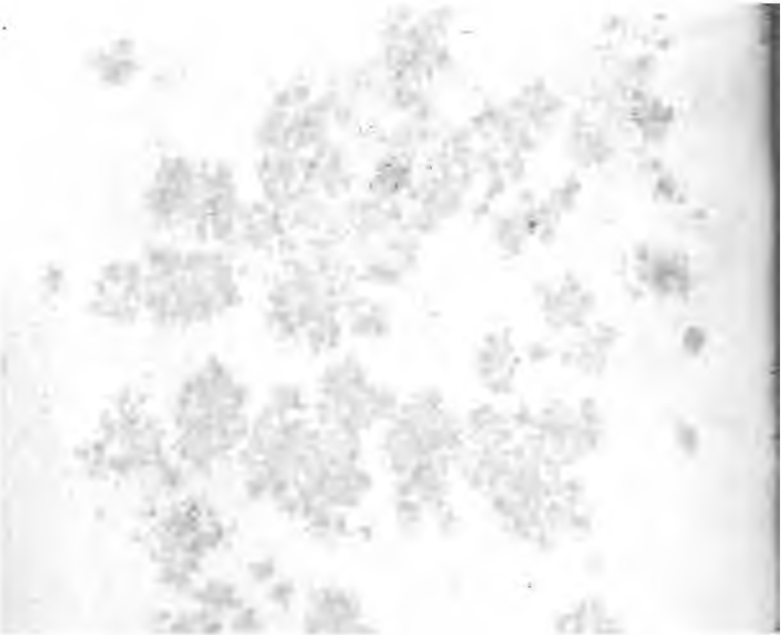

TEXT-BOOKS OF SCIENCE

ADAPTED FOR THE USE OF

ARTISANS AND STUDENTS IN PUBLIC AND SCIENCE SCHOOLS

RAILWAY APPLIANCES

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RAILWAY APPLIANCES

A DESCRIPTION OF

DETAILS OF RAILWAY CONSTRUCTION

SUBSEQUENT TO THE COMPLETION OF THE EARTHWORKS AND STRUCTURES

INCLUDING A

SHORT NOTICE OF RAILWAY ROLLING STOCK

BY

JOHN WOLFE BARRY

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WITH ILLUSTRATIONS

LONDON

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1876

PREFACE.

THE PURPOSE of this work is to describe the different material adjuncts, the appliance of which marks the distinction between the mere road bed, more or less straight and level, on which the rails are laid, and that elaborate system for the safe and speedy conveyance of passengers and goods which is practically known and talked of under the vague designation of a *railway*. The book is thus not intended to deal with the construction of the earthworks, bridges, and viaducts, on the one hand, nor with the financial management of the company on the other, but with the intermediate though equally important matters which complete the railway and which are necessary for working the traffic.

The ground thus proposed to be covered is very wide, and the size of this volume has rendered it necessary to exercise a somewhat arbitrary process of selection. It has not been possible to comprise within such moderate limits a description of many varieties in the multifarious details which present themselves in the ordinary practice of a railway engineer. With regard to the locomotive engine itself, especially, the subject is so large that it has been thought better not to attempt to deal with it in a chapter of

this work. The book will answer its intention if it supplies to the general reader a succinct but faithful description of the mechanical appliances on which the safe and punctual carriage of himself and of his consignments depends, and if the student of railway engineering acquires from it a correct and fairly complete introduction to the studies which lie before him.

To the general reader, the matters involving questions of public administration, or of principles of design, such as the control of railways by the Legislature and the Board of Trade, referred to in Chapter I.; some of the considerations affecting the design of rails and of wheels (pp. 64–68); the dangers of facing points (pp. 85–89); the introduction and general results of the interlocking of points and signals (pp. 108–113); the distinctive features of the block system of signalling (pp. 138–144); the advantages and drawbacks of the block system (pp. 165–171); the principles that should be followed in devising and adopting safety appliances (pp. 172–180); the arrangements or block plans of terminal stations (pp. 190–197); the safeguards in modern rolling-stock for lessening the effects of collisions (pp. 249–252), with the cognate subjects of continuous breaks and of communication between guards and drivers (pp. 284–293); will probably be more interesting than the pages devoted to the detailed arrangements by which the principles in question are carried into effect.

To the engineering student, however, the description and more detailed examination of the principal parts of the permanent way, signals, station-fittings, and rolling-stock, with special reference to the causes of the great wear and tear of railway plant and to the safety and convenience of working, will, it is hoped, be at least as useful as the con-

sideration of the matters of principle, with a view to which those parts are designed.

The review of some of the details cannot but indicate certain points in which there seems to be room for improvement in the design, or in the mode of using, railway appliances, and may perhaps suggest the direction in which improvements may possibly be made. It cannot be too strongly urged that in railway details there ought to be no finality in design; for although a most remarkable and creditable degree of safety has been attained in the conduct of English railway traffic (which, it should be remembered, is in point of amount and complexity unexampled in other countries), yet it cannot be denied that there is still scope for improvement, in greater freedom from what are (not always rightly) called 'railway accidents.' The reduction of working expenses, also, which on the average of the railway traffic of the United Kingdom have been rising steadily from 48·4 per cent. of the gross receipts in 1871 to 55·6 per cent. in 1874, is a subject, the importance of which may be appreciated, when it is considered that three per cent. of saving would amount to no less a sum than 1,000,000*l.* annually. No inconsiderable amount of the working expenses, and not a few of the risks of railway accidents are determined by the design and use of those details of railway appliances which it is the aim of this work to bring before the reader.

The Author regards as a popular error the supposition which is from time to time advanced, that railway engineers and managers are, as a body, remiss in attention to the safety or convenience of the public. From personal experience he can vouch for the care, foresight, and anxiety which are bestowed on these subjects by those in charge of our railways. But the extraordinary growth of the

traffic on English lines renders necessary the adoption of many precautions which were unknown twenty years ago, and the rejection or alteration of many well-known and well-tried appliances which were fully equal to the exigencies of former times.

In conclusion the Author begs to render his sincere thanks to many of his friends, professionally concerned either in the construction or in the working of railways, for the many valuable aids which they have rendered him in the task, by no means an easy one, of writing an elementary work on so large a subject.

23 DELAHAY STREET, WESTMINSTER:
December 1875.

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RAILWAY APPLIANCES.

CHAPTER I.

ACTS OF PARLIAMENT AND OTHER REGULATIONS AFFECTING RAILWAYS.

IN this work it is proposed to deal only with those parts of a railway which are executed subsequently to the main works by which the permanent way is supported; and it is not intended to describe, or treat of, the mode of construction of the main works, such as embankments, cuttings, bridges, tunnels, viaducts, and the like; which subjects belong, naturally to a treatise on civil engineering.

Before entering, however, upon the Details of Railway Appliances, a few pages will be devoted to the consideration of the statutes and regulations affecting the construction of railways. It is so difficult to draw a sharp line of distinction between the enactments which refer to the main construction works and those whieh refer to the appliances of a railway, that it has seemed best to describe briefly the main provisions of the Acts of Parliament and other regulations which control the construction and working of a railway, though in so doing reference will of necessity be often made to the main works wnich lie beyond the scope of the subject of Railway Appliances.

There are certain general Acts of Parliament and certain general regulations which apply to all railways constructed

in the United Kingdom. The most important of these are the Lands Clauses Consolidation Act (1845), the Railways Clauses Consolidation Act (1845), the Act regulating the gauge of Railways (1846), the Railways Clauses Act (1863), the Standing Orders of Parliament, and the Regulations of the Board of Trade. The Lands Clauses Act applies to all undertakings involving the compulsory taking of land, and in that respect it is a most important Act of Parliament affecting railways. Its particular scope is the regulation of the acquisition of the land required, the clauses referring to which are numerous and minutely specific in their directions; but as it does not immediately concern the mode of construction adopted on a railway or the subsequent working of the traffic, a passing reference to it will suffice for the objects of this work. An accurate knowledge of this Act is, however, required for any one engaged in the laying out of a railway, as its regulations in many cases materially influence the course and magnitude of the proposed work. The other Acts of Parliament above mentioned, the Standing Orders, and the Regulations of the Board of Trade, will be referred to in some detail, so far as the enactments contained in them govern the construction and working of railways.

As the formation of a railway involves the acquisition of a continuous strip of land, it is evident that it can seldom be made without serious interference with the rights of property. Not only must the soil be acquired on which to place the railway, but it is impossible to cut a strip out of an estate, and use the strip for railway purposes, without at the same time affecting the adjoining land. In some exceptional cases, where all the owners of property adjoining the intended railway and all other persons interested are agreed on the desirability of the proposed line, and where no interference takes place with the general rights of the public, a railway can be made without the authority of Parliament. These cases are, however, of rare occurrence; and, speaking gene-

rally, a railway in this country cannot be made without the privileges and immunities of an Act of Parliament; or, what is much the same thing, of a Provisional Order of the Board of Trade.

An Act of Parliament, or a Provisional Order, proceeds on the assumption that the construction of the railway in question is for the public advantage; and the truth of this assumption is one of the points which, when an application to Parliament is made by a railway company, is frequently hotly contested by opponents of the line.

Granting that the construction of a railway is for the public advantage, it is expedient that, on proper compensation being given, the rights of private owners should give way to the general good of the community. A railway company's Act of Parliament, in conferring on the company the right to construct and work the railway, grants to the company also the power to acquire compulsorily such lands or buildings as are required for the line and the stations. All lands or buildings so required must be accurately delineated on plans, and described in books of reference attached to such plans. Both plans and books of reference must be deposited at certain specified places, where they are by law open to public inspection.

The rights granted to the company are at the same time hedged round with various conditions, designed for the protection and compensation of persons affected by the construction of the line. The ordinary protective clauses, under which the compulsory powers are granted, are contained in general Acts of Parliament, the most important of which is the Lands Clauses Consolidation Act (1845). This Act is embodied in all special Acts which give to companies or individuals compulsory powers for the acquisition of property. In exceptional cases special protective clauses are inserted in the special Act.

The word 'compensation' is not to be understood as meaning only money compensation. It includes all works

and conveniences which any persons have a right to require, and which a railway company may be required or may agree to construct, so as to modify and diminish the damage done by the construction of the railway.

Parliament has also to be satisfied that the proposed railway is to be so constructed as to be safe and efficient; and that it is to be worked in such a way as not to unduly interfere with the rights and comfort of adjoining landowners, tenants, or of the public at large. The general conditions, intended to secure these requirements, are contained in a general Act of Parliament, called the Railways Clauses Consolidation Act 1845, which, like the Lands Clauses Consolidation Act, is always embodied in the special Acts authorizing the construction of railways.

An engineer, therefore, has in the first place to prepare plans and books of reference, which shall accurately describe the lands he proposes to acquire, subject to the limitations and conditions of the Lands Clauses Consolidation Act; and secondly, he must prepare sections of the proposed railway, showing what gradients, cuttings, embankments, tunnels, viaducts, bridges, and other works will be required, subject to the general conditions of the Railways Clauses Act. In some very rare cases a special Act of Parliament, authorizing a work of an exceptional character, will allow some of the conditions of the two general Acts to be set aside; but Parliamentary committees are jealous of granting such exceptional powers, and a strong case has to be made out before they are given.

Further, in order to ensure uniformity, Parliament has adopted certain rules for the preparation of plans and sections, defining within certain limits the mode of delineating the lands required, and the way in which the line and works of the proposed railway are to be indicated; so that accurate information may be at all times accessible in an intelligible form, as to the course, length, curves, gradients, and structural works on the line. These rules are embodied in a series

of Standing Orders, which must be rigidly adhered to, and any breach of these may cause the absolute rejection of any application to Parliament.

With regard to the plans and sections to be deposited with the proper authorities, the following regulations are, *inter alia*, contained in the Standing Orders:—

Every plan must be drawn to a scale of not less than four inches to a mile, and must delineate all lands or houses within the limits of deviation, all of which are to be numbered with reference numbers.

The limits of deviation are the limits within which the promoters apply for power to deviate the centre line of the railway laterally.

All parish and county boundaries must be shown on the plan.

Buildings must be shown on a scale of at least a quarter of an inch to a hundred feet. Thus, unless the plan is throughout on this large scale (as is very frequently the case in railways passing through towns), the buildings have to be shown on an enlarged scale.

The distances from one of the termini of the railway are to be marked in miles and furlongs.

The radius of every curve of less radius than one mile is to be marked in furlongs and chains.

All tunnels are to be marked with a dotted line.

All proposed diversions of public roads, rivers, canals or railways, are to be shown.

Wherever it is proposed to make a junction with an existing railway, the course of such railway is to be shown on the plan for a distance of 800 yards on each side of the junction.

A book of reference has to be prepared, which must contain the names of the owners, lessees and occupiers, of all lands and houses in every parish within the limits of deviation shown on the plan, with a short description of such lands and houses. The book of reference describes each property, first by a number corresponding with the number

placed on such property on the plan, and then by a statement of the nature of the property, whether 'field,' 'park,' 'road,' 'house,' 'river,' or 'railway;' and appends to the description the name first of the owner, secondly of the lessees, and thirdly of the occupiers. By means of the plan and the book of reference anyone ought to be able to see whether his property is to be intersected by the proposed railway or is contained within the limits of deviation.

The section must be drawn to the same horizontal scale as the plan, and the vertical scale of it must not be less than an inch to 100 feet. It must show the surface of the ground traversed by the centre line of the railway, the height of every embankment, and the depth of every cutting. It must also show the level of the upper surface of the rails of the proposed railway above a horizontal datum line, and the rate of inclination of every gradient is to be marked. Any tunnels must also be shown on the section.

The following must be marked in figures on the section: viz. the height of the railway above the datum line at the beginning and end of every gradient; the height of the railway above or the depth below every public road, river, canal, or railway; the height and span of all bridges or viaducts, over the same; the greatest vertical height of every embankment or cutting, when such height exceeds five feet; the heights of all viaducts, and the depths of all tunnels.

If any level crossings of public roads or railways are intended, they must be described on the section. If any alteration is intended to be made in the level or rate of inclination of any public road or railway which will be crossed by the proposed railway, a memorandum of such alteration is to be made on the section, and cross sections to a prescribed scale are to be added, which cross sections must extend for 200 yards on each side of the centre line of railway.

If a junction is intended to be made with an existing railway, the gradient of such railway is to be shown on the section for a length of 800 yards on each side of the junction.

The Standing Orders further require an estimate of the cost of all railways, as nearly as may be, in the following form :—

Estimate of the Proposed Railway.

Line No. . Whether single or double .

Length of line miles fur. chs.

	Cubic yards	Price per yard	£ s. d.	£ s. d.
Earthworks				
Cuttings—Rock . .				
Soft soil . .				
Roads . .				
Total				
Embankments including roads cubic yards .				
Bridges, public roads, , Number				
Accommodation bridges and works				
Viaducts				
Culverts and drains				
Metallings of roads and level crossings				
Gatekeepers' houses at level crossings				
Permanent way, including fencing : miles fur. chs. at			Cost per mile £ s. d.	
Permanent way for sidings and cost of junctions . .				
Stations				
Contingencies , per cent. . . .				
Land and buildings acres roods perches .				
Total				£

The above matters are the principal requirements of the Standing Orders, so far as civil engineering is concerned.

Under the Railways Clauses Act the following are some of the most important of the requirements to be borne in mind in laying out and constructing a line :—

1. No deviation from the levels shown on the deposited section may be made to a greater extent than five feet in

the country, or than two feet in towns, except with the consent of the owners of the adjoining property.

2. No alteration may be made in gradients, curves, tunnels, or other engineering works, except as under :—

a. Any gradient may be made less steep than shown on the section.

b. Gradients less than 1 in 100 may be altered to the extent of 10 feet in a mile. Thus a gradient of 1 in 160, which is equivalent to 33 feet in a mile, may be made 1 in 123, which is equivalent to 43 feet in a mile.

c. Gradients steeper than 1 in 100 may be altered to the extent of 3 feet in a mile. Thus a gradient of 1 in 90, which is equivalent to 58·66 feet in a mile, may be made 1 in 85·63, which is equivalent to 61·66 feet in a mile.

d. Any curve may be made with a greater radius than that shown on the plan.

e. Curves of less radius than half a mile may not be made of smaller radius; but curves of greater radius than half a mile may be altered to that radius.

In all the above cases the Board of Trade may authorize a further deviation if the company apply to the Board for permission. Also, if the Board of Trade consent, a cutting may be replaced by a tunnel, or an embankment by a viaduct.

3. The company may deviate to the following extent from the line of the railway shown on the deposited plans, provided such deviation is within the limits of deviation shown on the deposited plans :—

a. In towns or lands continuously built upon, to the extent of 10 yards on either side of the centre line.

b. In the country to the extent of 100 yards on either side of the centre line. Such deviation must not, however, be made, if in so doing the line be carried into lands not included in the book of reference, except with the consent of the owner of the land in question.[1]

[1] Further powers in respect of alterations in engineering works are given to the Board of Trade by the Railways Clauses Act, 1863 (see page 14).

4. Railways are not allowed to cross public roads on the level unless a distinct authority to do so be given by the special Act. If a level crossing of a public road be permitted, gates must be erected and a gatekeeper employed. [This provision with respect to the gatekeeper is of importance, as in many cases it is cheaper in the long run to build a bridge than to pay the wages of a gatekeeper who must be constantly at the level crossing. Reckoning the wages of the gatekeeper at 1*l.* a week, and assuming that (as in many cases is necessary) the services of two men are required—viz. one on duty and one off duty – a public road level crossing entails a yearly expenditure by the company of 104*l.* in wages. This sum capitalized at 5 per cent., or 20 years' purchase, comes to 2,080*l.* If only one man is wanted the capitalized sum would be 1,040*l.*, and even this latter sum is above the average cost of an ordinary public road bridge.]

5. With regard to bridges for roads under the railway, the following regulations are obligatory:—

a. A turnpike road bridge must be at least 35 feet wide in the clear between the abutments, and must have a clear headway of 16 feet in height for a minimum width of 12 feet (see fig. 1).

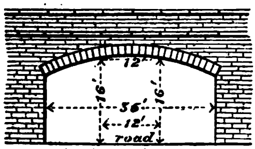


Fig. 1. Turnpike road bridge.

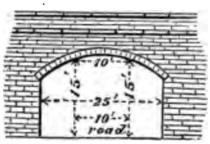


Fig. 2. Public carriage road bridge.

b. A public carriage road bridge must be 25 feet wide in the clear, with a headway of 15 feet for a mininum width of 10 feet (see fig. 2).

c. A private or occupation road bridge must be 12 feet wide in the clear, with a headway of 14 feet for a minimum width of 9 feet (see fig. 3).

The sketches explain what is intended by the regulations

as to headway of bridges under railways. The dimensions for width must in skew bridges be measured on the square or at right angles to the direction of the road.

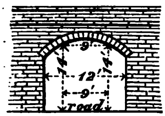


Fig. 3. Occupation road bridge.

6. Bridges carried over the railway must have the same width in the clear, measured on the square, between the parapets, as bridges under the railway. The headway under these bridges is a question which is left to the railway company. The archways must of course be wide enough and high enough to accommodate the railway company's rolling stock. The ordinary minimum headway is 14 feet, and occasionally the arch is made of such a height and shape as barely to accommodate the funnel of the locomotive, and to allow the broadest vehicle on the railway to pass beneath it (see fig. 4). The ordinary mininum width for a double line of way of narrow gauge under a bridge is 23 feet 3 inches, which is arrived at as follows :—

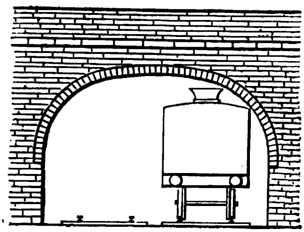


Fig. 4. Minimum structure.

	Ft.	Ins.
Two lines of way (4 ft. 8½ ins. each between rails) .	9	5
Width of rails (4 times 2½ ins.)	0	10
Space between lines of way	6	0
Spaces between rails and side walls of bridge (twice 3 ft. 6 ins.)	7	0
Total	23	3

The spaces between the rails and the side walls are generally made wider than the above dimensions, so as to avoid any risk of carriages striking platelayers or other persons employed on the railway. The boundary lines arrived at from the minimum width and minimum headway are called the lines of minimum structure.

7. In carrying a road over or under a railway it often

happens that the road has to be raised or depressed, and the gradient of the road has to be altered. The gradient of such alteration need not be better than an existing gradient on the same road within 250 yards of the point of crossing; but where the existing gradients within 250 yards of the point of crossing are better than those mentioned below, the worst gradients permitted to be used are as follows:—

Turnpike roads, 1 in 30.
Public carriage roads, 1 in 25.
Private or occupation roads, 1 in 16.

The fences for bridges over a railway are prescribed by the Act to be at least 4 feet high on the bridge itself, and 3 feet high on the approaches to the bridge.

8. A railway company need not construct public road bridges either over or under their line, of a greater width than that of the road within 50 yards of the point of crossing; provided, however, that in no case shall the bridge be narrower than 20 feet. If under this provision a bridge be constructed of less than the proper width for the particular class of road, the company must widen it to the proper width, if at any time subsequently to the construction of the bridge the road be widened.

This permission to build under bridges narrower than the specified width for the particular class of road is seldom acted upon, as it is generally more prudent for the railway company to construct the bridge of the full width at the outset. The inconvenience and expense of widening a bridge when the railway is in operation is considerable, while the cost of an additional 5 or 10 feet in the span of a bridge is not, in most cases, a large addition to the first cost of the structure. The additional width adds but little to the cost of the abutments, or of the wing walls, and involves only an extra expenditure in the arch or in the girders spanning the opening

In towns it is generally the custom for railway companies

to propose, in their Parliamentary plans, bridges of the full width of the streets, where the street is wider than the dimensions above prescribed for turnpike or public carriage roads, although the Railways Clauses Act does not compel this course. It is doubtless sound policy of the company to offer to give bridges of the full width of the street, as by so doing they disarm the opposition of the local authorities, while, in all probability, Parliament would, either at the instance of the local authorities or of the Board of Trade, insist by special clauses that the streets should not be contracted in width by the works of the railway company.

9. Bridges carrying railways over roads are in certain cases to have screens, so that the engines and carriages are hidden from the sight of horses on the road. These screens must be erected by the company, if the commissioners of a turnpike road, or the surveyor of a public carriage road, memorialize the Board of Trade, and satisfy the Board that the sight of the engines and carriages involves danger to the passengers on the road, and that such danger might be obviated or lessened by the erection of a screen.

10. The line must be measured, and the distances marked from one of the termini at every quarter of a mile, and the company must exhibit on boards, to be placed in conspicuous places, short particulars of the offences against their bye-laws to which penalties are attached.

11. The Railways Clauses Act contains numerous provisions with respect to the accommodation works to be constructed, so as to lessen as far as possible the damage to landowners and other private individuals from the construction of the railway. Thus,

a. Where lands are severed, the railway company is bound to build bridges, arches, gates, culverts, or passages over or under, or by the side of the railway, so as to make good any interruption caused by the railway to the use of the land through which the railway is made.

b. The railway is to be efficiently fenced off by posts,

rails, hedges, ditches, mounds, or other fences, to protect the lands adjoining the railway from trespass, and to prevent cattle from straying; all necessary gates are to be provided, and these gates must open towards the adjoining lands, and not towards the railway.

c. Drains and culverts are to be built under or over the railway, of sufficient dimensions to convey the water off land adjoining the railway as efficiently as was the case before the making of the railway. Watering-places for cattle are to be provided, where access to previously existing watering-places is destroyed by the construction of the railway.

d. Accommodation works need not be made, if they would obstruct the working or using of the railway; and further, the railway company need not make them if they have agreed with the owners and occupiers of the land to pay them a sum of money in lieu of making the accommodation works. On all differences between the landowners and the company, as to the kind and number of accommodation works, a reference is given to two justices of the peace, who have power to settle such points, and also to appoint the time within which the works (if any) shall be executed by the company. The company are not compelled to execute any further accommodation works after the expiration of the period fixed by the justices; or, if no period is prescribed, after five years from the completion of the works and the opening of the railway for public use.

e. Landowners may execute any further accommodation works at their own expense, provided—that such works shall be executed to the satisfaction of the company's engineer; who may not, however, put the landowner to a greater cost than is incurred in similar works executed by the company.

The above are some of the principal regulations of the Railways Clauses Act, having reference to the construction and details of railways, but it is not possible to do more than refer generally to the provisions of that comprehensive statute.

As part of this survey of the Acts of Parliament regulating the making of railways. it is necessary to advert to the 9 and 10 Vict. cap 57 (1846), which fixed the standard gauges of English and Irish lines.

The standard gauge of Great Britain is 4 ft. 8½ in., measured between the rails. The standard gauge for Ireland is 5 ft. 3 in. measured between the rails. All railways in the United Kingdom must be made to and maintained at these gauges, with certain exceptions, viz. (1) such railways as had Acts of Parliament in 1846 authorising their construction on gauges different from the standard gauge. (2) The Great Western Railway system and its affiliated lines, over which a gauge of 7 feet is legalised. In certain districts of the Great Western system the company is allowed to lay down what is termed the mixed gauge, viz. the broad gauge of 7 feet with a third rail between the rails of the broad gauge to accommodate the narrow gauge (4 ft. 8½ in.) stock.[1]

This Act of Parliament enacts that the gauge of a line may not be altered, and imposes penalties for constructing lines on any gauges other than those authorised.

The next Act of Parliament of importance is the Railways Clauses Act 1863, which may be regarded as supplemental to the Railways Clauses Act 1845, of which so much has been said above.

The most important of the provisions in the Act of 1863, with respect to railway construction, are the following :—

Power is given to the Board of Trade to authorise the company, in the construction of a railway, to deviate from the line or level of any arch, tunnel, or viaduct, described in the deposited plans or sections, subject to the general regulations of the Act of 1845 referring to those structures, provided that the nature of the work described in the deposited plans or sections be not altered; or to sub-

[1] Under special conditions Parliament will allow a gauge differing from the standard gauge to be used, and of late years gauges much narrower than 4 ft. 8½ in. have been occasionally employed. The narrowest gauge laid on a public railway in this country is that of the Festiniog *Railway,* which is 2 ft.

stitute any engineering work not shown on the deposited plans or sections for an arch, tunnel, or viaduct, as shown thereon. The Board of Trade must be satisfied that the company has acted in the matter in good faith; that the owners, lessees, and occupiers of the lands in which the substitution is to be made consent thereto; and also that the safety and convenience of the public will not be diminished by the substitution.

The railway company is compelled to erect and maintain a lodge at level crossings of public roads. The Board of Trade have power to require a bridge to be built, in place of any level crossing of a public road; or may, instead of a bridge, require other works to be done for the purpose of removing or diminishing the danger of such level crossing. This power only applies to railways made under Acts of Parliament of later date than 1863.

When one railway forms a junction with another, the works of the junction are to be made to the satisfaction of the engineer of the older line, and the regulation of the working of the junction must be in the hands of the officials of the older line; but all the current expenses of the junction (such as the erection and maintenance of the signals, wages of pointsmen and watchmen), and all incidental current expenses, are to be borne by the newer company. With regard to the construction of railways across tidal lands or tidal water, railway companies must take care that such works are properly lighted at night, to prevent accidents to ships from running against the works. If the spans of bridges are not defined by the special Act, the Board of Trade can settle what spans are to be used. In the case of opening or swing bridges, the railway company is not to delay the traffic of the river more than for the time absolutely required for a train to cross the river. Where works of a railway cut off access from lands previously contiguous with tidal water, the company are to construct such bridges or level crossings as the Board of Trade may direct. The company must not deviate from the authorised centre line

of a railway skirting a public navigable tidal river or channel, in such a way as to diminish the navigable space, without the consent of the Board of Trade, even though the limits of deviation may be drawn in such a way as would permit such deviation of the centre line in other cases. If a work constructed by a railway company on, in, over, through, or across tidal lands or water, is abandoned, or falls into decay, the Board of Trade may remove the work at the expense of the company.

The above pages briefly indicate the general scope of the Acts of Parliament referring to the construction of railways; but it is absolutely necessary that engineers should have an intimate knowledge of the Acts themselves before they begin the designing of a railway in Great Britain or Ireland. Engineering work in this country is so much governed by either general or special Acts of Parliament, that engineers must possess a knowledge of law greater than is required for other professions.

The next subjects which naturally present themselves for consideration are the requirements of the Board of Trade. Every railway company intending to open a new line for passenger traffic is required by the Act 5 & 6 Vict. cap. 55 to give one month's notice of their intention to the Board of Trade, and a subsequent notice ten days before the railway will be, in the opinion of the company, sufficiently completed for the safe conveyance of passengers and ready for inspection.

If the line be not found, on inspection by the officers of the Board of Trade, to be in a safe condition for passenger traffic, the Board of Trade may postpone the opening from month to month, till it shall appear to them that the railway is in a fit state; and if the line be opened without the permission of the Board, the company will forfeit 20*l.* per day for every day on which the line remains open without permission.

Apparently, as the law stands, a railway company may,

if it choose to pay 20*l.* a day, open a new line without inspection, and the Board of Trade seems to have no power to shut up a railway. Neither is power given to the Board of Trade to inspect a line after it is opened, or to order any improvements on an old line, or to interfere, except by making recommendations and suggestions, with the working of an old line, unless the company owning it undertake new works connected with the old line; in which case the new works are subject to inspection, and the inspecting officers have then an opportunity of revising the old works so far as they are connected with the new works. From this follows the curious anomaly that the Board of Trade may require numerous and probably salutary precautions to be provided on new lines, while old lines, possibly with ten times the traffic, may be, and occasionally are being, worked without those precautions. It is true that the Board have various powers in other matters connected with railways after they are opened for traffic; but except in one or two specified and unimportant cases, they have no power over the works or the regulation of the traffic of old lines.

All new railways, however, must be inspected and certified by the officers of the Board of Trade, prior to their being opened for passenger traffic; and there are general rules published by the Board, as guides to their inspecting officers as well as to the engineers in the construction of the line. The inspecting officers have a dispensing power with regard to these requirements; but, as a rule, they must be observed, or the certificate of the Board will not be given. As the requirements are tersely expressed in the circular of the Board, the portions relating to the construction of the railway are subjoined *verbatim*. Other portions relate to the mode of working single lines of railway and to other matters; but, as these do not refer directly to the matters under consideration, they may be omitted.

Extract from Circular of the Board of Trade.

Memorandum of Important Requirements.

1. The requisite apparatus to be provided at the period of inspection for ensuring an adequate interval of space between following trains.

2. Home-signals and distant-signals for each direction to be supplied at stations and junctions, with extra signals for such sidings as are used either for the arrival or for the departure of trains.

3. The levers and handles of points and signals to be brought close together, into the position most convenient for the person working them, and to be interlocked. The points to be provided with double connecting rods. The levers of the points to be sufficiently long to enable the pointsmen to work them without risk or inconvenience, and not to be placed on the ground between the lines of rails. All signals which are worked by a wire should be so weighted as to fly to 'danger' on the fracture of the wire.

4. Facing points to be avoided as far as possible.

5. It being necessary that a uniform system of signals should be adopted on all railways, the semaphore arms should, at stations and junctions where there is more than one on one side of a post, be made in future to apply, the first or upper arm to the line on the left, the second arm to the line next in order from the left, and so on. In the case of sidings, a low and short arm, distinct from the arm or arms for the passenger lines, may be employed. Clocks should be placed in conspicuous positions for the use of the signalmen.

6. The signal handles and the levers of the points should be brought together under cover upon a properly constructed stage, with glass sides enclosing the apparatus. They should be so arranged that while the signals are at danger the points shall be free to move; that a signalman shall be

unable to lower a signal for the approach of a train until after he has set the points in the proper direction for it to pass; that it shall not be possible for him to exhibit at the same moment any two signals that can lead to a collision between two trains; and that after having lowered his signals to allow a train to pass, he shall not be able to move his points so as to cause an accident or to admit of a collision between any two trains. The facing points should be provided with apparatus which will ensure the points being in their proper positions before the signals are lowered, and which will prevent the signalman from shifting the points whilst a train is passing them. Every signalman should be able to see the arms and the lamps of his home- as well as his distant-signals, and the working of his points. The fixed lights in the signal-cabins should be screened off, so as not to be mistakeable during fogs for the signals exhibited to control the running of trains.

7. The junctions between passenger lines and any sidings should be protected by a home-signal and a distant-signal in each direction. The sidings should be so arranged that the shunting carried on at them shall present the least possible obstruction to the passenger lines; and there should be a blind siding or dead end, with the points closed against the passenger lines and interlocked with the signals.

8. When a junction is situated near to a passenger station, or is connected with goods or mineral sidings, the platforms and sidings should be so arranged as to prevent, as far as possible, any necessity for shunting over the junction.

9. When two single lines meet, the junction should in ordinary cases be formed as a double-line junction.

10. The lines of railway leading to the passenger platforms to be so arranged that the engines shall always be in front of the passenger trains as they arrive at and depart from a station, and that each line shall have its own platform.

11. Platforms to be continuous and not *less* than 6 feet wide for stations of small traffic, nor less than 12 feet wide for important stations; and the descent at the ends of the platforms to be by ramps, and not by steps. Pillars or columns for the support of roofs, or other fixed works, not to be nearer to the edge of the platforms than 6 feet. It is considered desirable that the height of the platforms above the rails should be 2 feet 6 inches, the minimum height to be 1 foot 9 inches.

12. When stations occur on or near a viaduct or a bridge under the railway, a parapet or fence on each side should be provided, sufficient to prevent passengers falling from the viaduct or bridge in the dark. All viaducts under the railway should be provided with handrails and with projecting platforms for the protection and escape of the platelayers. Viaducts of timber and iron should be provided with man-holes and other facilities for inspection.

13. The steps of staircases approaching stations, and of foot bridges over the lines, and of foot subways, to be not less than 11 inches in the tread, or more than 7 inches in the rise, and all such staircases to be provided with efficient handrails.

14. Clocks to be provided at all stations, in positions where they are visible from the line.

15. Turntables for engines, of sufficient diameter to enable the longest engines and tenders in use on the line to be turned without being uncoupled, to be erected at terminal stations, and at junctions and other places at which the engines require to be turned. Care should be taken to keep all turntables at safe distances from adjacent lines of rails, so that engines, waggons, or carriages, when being turned, may not foul other lines, or endanger the traffic upon them.

16. No station to be constructed on a steeper gradient than 1 in 260, except where it is unavoidable. When the gradient at a station is necessarily steeper and the line is

double, and when danger is to be apprehended from vehicles running back, a catch-siding, with points weighted for the siding, should be provided further down the incline than the passenger platform and goods-yard, to intercept run-away vehicles. When the line is single a second line should be laid down, a second platform constructed, and a catch-siding similarly provided.

17. In a cast-iron bridge the breaking weight of the girders should be not less than three times the permanent load due to the weight of the superstructure, added to six times the greatest moving load that can be brought upon it.

18. In a wrought-iron bridge the greatest load which can be brought upon it, added to the weight of the superstructure, should not produce a greater strain on any part of the material than five tons per square inch.

The above maximum strain for wrought-iron bridges was adopted after due investigation by, and on the authority of, a Royal Commission. Until similar investigations have been made in regard to steel, and its various qualities, by an equally competent tribunal, it is impossible to adopt rules for the strains which should be permitted in the employment of that material.

The heaviest engines in use on railways afford a measure of the greatest moving loads to which a bridge can be subjected. These rules apply equally to the main and the transverse girders. The latter should be calculated for the heaviest weights carried by the driving wheels of locomotive engines.

19. The upper surfaces of the wooden platforms of bridges and viaducts should be protected from fire.

20. The joints of the rails should be secured by means of fish-plates, or by some other equally secure fastening. The weight of the cast-iron chairs on branch lines, or lines on which the traffic will be small and light, and where it will be worked by engines of ordinary construction, should be

not less than 26 lbs. each; but on main lines, and where heavy traffic may be worked at high speed, the chairs should weigh not less than from 28 to 30 lbs.

21. When chairs are used to support the rails, they should be secured to the sleepers, at least partially, by iron spikes or bolts. With flat-bottomed rails, when there are no chairs, or with bridge rails, fang or other through-bolts, should be used, at least at the joints and in some intermediate places.

22. No standing work (other than a passenger platform) should be nearer to the side of the widest carriage in use on the line than 2 ft. 4 in., at any point between the level of 2 ft. 6 in. above the rails, and the level of the upper parts of the highest carriage doors. This applies to all arches, abutments, piers, supports, girders, tunnels, bridges, roofs, walls, posts, tanks, signals, fences, and other works; and to all projections at the side of a railway, constructed to any gauge.

23. The intervals between adjacent lines of rails, or between lines of rails and sidings, should not be less than 6 ft.

24. At all level crossings of turnpike and public roads, the gates should be so constructed as to close across the railway, as well as across the road, at each side of the crossing. They should not be capable of being opened at the same time for the road and the railway. A lodge or station-house should be provided, as is required by Act of Parliament. When a level crossing occurs at a station, there should be a box, if there is not a lodge, at the gates, for the use of the gate-keeper. Wooden gates are considered preferable to iron gates for closing across the railway.

25. The fixed signals attached to the gates at the level crossings should be placed in convenient positions for being seen along the railway as well as along the road. When a level crossing is so situated that an approaching train cannot be seen from a sufficient distance, distant-signals (which may both be worked by one lever) should be supplied.

26. Mile-posts, and quarter and half-mile posts, and gradient-boards, should be provided along the road.

27. Tunnels should in all cases be constructed with recesses for the escape of the plate-layers.

Precautions Recommended in the Working of Railways.

1. There should be a break-vehicle with a guard in it at the tail of every train; this vehicle should be provided with a raised roof and extended sides, glazed to the front and back; and it should be the duty of the guard to keep a constant look-out from it along his train.

2. There should be a means of intercommunication between a guard at the tail of every passenger train and the engine driver, and between the passengers and the servants of the company.

3. There should be at least one break-vehicle to every three or four carriages in a passenger train, a proportion which may be economically provided by the use of continuous breaks. On steep inclines, and with trains which travel at high speed, a larger proportion of break-power is required.

4. The tyres of all wheels should be so secured to the rims of the wheels as to prevent them from flying open when they are fractured.

5. The engines employed with passenger trains should be of a steady description, with not less than six wheels, with a long wheel-base, with the centre of gravity in front of the driving wheels, and with the motions balanced. They should not be run tender first.

6. Records should be carefully kept of the work performed by the wearing parts of the rolling stock, to afford practical information in regard to them, and to prevent them from being retained in use longer than is desirable.

7. When a line is worked by telegraph, the telegraph-huts should be commodious, and should be supplied with clocks, with record-books, with a separate needle for signal-

ling the trains on each line of rails, and with an extra needle for other necessary communications between the signalmen. The telegraph instruments and signal-handles should face the directions in which they work.

8. When drovers or other persons are permitted to travel with goods or cattle trains, suitable vehicles should be provided for their accommodation near the front of such trains.

9. Luggage should not be carried on the roofs of railway carriages.

10. The names of the stations should be marked on the lamps, besides being shown on other conspicuous places.

The Regulations of Parliament and of the Board of Trade above referred to comprise the legislative requirements to which railway companies must (more or less) conform, both as to the larger works of construction and in the appliances for working the railways. The construction works have to be designed with special reference to the details of the appliances for working and using the railway, and the appliances have to be made to conform to the general conditions of the construction works. It has been therefore thought desirable, in this Introductory Chapter, to deal generally with the legislative enactments. But in all that follows, since (as has been already said) it is not intended to enter even cursorily into the engineering of the main works of a railway, it will be assumed that the embankments, cuttings, tunnels, viaducts, bridges, and other structural works, are executed, and that the works and appliances necessary to complete the line have alone to be considered.

CHAPTER II.

PERMANENT WAY.

THE level of the top of the embankments and of the bottom of the cuttings of a railway is called the formation level. Above the formation level is placed the ballast, and on the ballast the permanent way, which consists of sleepers, chairs, fastenings, rails, fish-plates, points, crossings, and all the materials which form the road on which the railway vehicles run.

The expression 'permanent way' is employed to distinguish the materials of the finished railway from the materials of the temporary tram-roads used by contractors during the construction of the line, for making the embankments or cuttings, and for carrying materials for the railway from one place to another.

Figs. 5 and 6 are cross sections of a single line of railway, and show the different parts of the permanent way, to each of which parts reference in detail will be made further on. In fig. 5 the line is shown with double-headed rails in chairs placed on cross sleepers, and in fig. 6 the line is shown with flat-bottomed or Vignoles rails resting on cross sleepers, but without chairs.

The width of the earthworks at formation level depends on the number of lines of way, the gauge of the railway, the length of the sleepers, the slopes of the ballast, and the width of the side ditches where these are required. This width is therefore generally greater in cuttings than it is on embankments, to afford space for side ditches for carrying

off the water which finds its way into the cuttings. The widths given to cuttings depend therefore on local considerations, as the side ditches require to be more capacious in certain situations and in certain soils than in others.

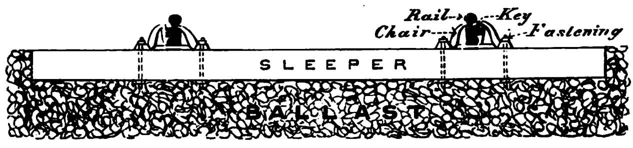


Fig. 5. Cross section of a railway with double-headed rails in chairs.

Fig. 6. Cross section of a railway with flat-bottomed rails.

The term 'line of way' signifies the road or track formed of two rails on which a railway train runs, and the gauge of the line is the distance between these two rails.

The space between lines of way is generally in this country at least 6 ft. in the clear between the outside edges of the rails. The gauge being also of a fixed width, the central part of a railway, or the distance between the outside rails, has an uniform width, while the space at the sides is, as has been explained above, dependent on variable conditions, such as the length of the cross sleepers used, and the necessity in places for side ditches.

The standard gauge of railway in Great Britain is 4 ft. 8½ in. for narrow gauge lines, and 7 ft. for the broad gauge lines, which latter are entirely comprised in the systems of the Great Western, the Bristol and Exeter, the South Devon, and Cornwall Railways.

The Great Western Railway, which was originally con-

structed and worked on the broad gauge of 7 feet, has now but few miles of exclusively broad gauge remaining. The rest of the Great Western Company's system is composed of 1,349 miles of narrow gauge, and of 122½ miles of mixed gauge. The part of its system on the mixed gauge is the portion which connects Bristol to London, and a few branches running out of it. As soon as the companies west of Bristol owning broad gauge lines joining the Great Western at Bristol are prepared to follow the example of the Great Western Company and lay down narrow or mixed gauge, which alteration will probably be made before long, England and Scotland will possess the great advantage of an unbroken gauge on all the main lines of railway.

There are a few mineral and private lines on a gauge narrower than 4 ft. 8½ in., but these are exceptional and isolated cases, where the narrowness of the gauge has been adopted for local and special purposes, and need not be referred to in detail.

The standard gauge of Ireland was settled by Act of Parliament in 1846 at 5 ft. 3 in. The standard gauge of British India until lately was exclusively 5 ft. 6 in., but now there are two gauges, viz. the 5 ft. 6 in. gauge, on the trunk lines, and a second gauge for subsidiary lines of 3 ft. 3·3708 in., or one French mètre.

The gauge over the greater part of Europe is the same as our standard narrow gauge, viz. 4 ft. 8½ in., but the Spanish gauge is 5 ft. 6 in., and the Russian gauge is 5 ft. In the United States the gauges vary from 3 ft. to 8 ft., and there is no standard gauge.

Some of the railways in the United States which are continuous differ slightly in gauge to the extent of one or two inches, and rolling stock is interchanged between those lines, though with the inconvenience of the wheels running tight or loose as the case may be. Attempts have been made to construct rolling stock with wheels which should be capable of sliding on their axles, so as to admit of adjustment

to different gauges, but the experiment has not been very successful.

Beneath are enumerated the gauges of some of the principal countries of the world, including those already referred to :—

		ft.	ins.		ft	ins.	ft.	ins.
Great Britain		4	8½	and	7	0		
Ireland		5	3					
British India		1 metre		and	5	6		
Ceylon		5	6					
Canada		4	8½	and	5	6		
Nova Scotia		4	8½	and	5	6		
Australia	New South Wales	4	8½					
	Victoria and South Australia	5	3					
	Queensland	3	6					
Tasmania		3	6					
New Zealand		5	3					
Cape Colonies		3	6					
France		4	8½					
North Germany		4	8½					
Russia		5	0					
Holland		4	8½					
Belgium		4	8½					
Austria		4	8½					
Hungary		4	8½					
Turkey		4	8½					
Switzerland		4	8½					
Italy		4	8½					
Norway		3	6	and	4	8½		
Sweden		4	8½					
Denmark		4	8½					
Spain		5	6					
Portugal		5	6					
Egypt		3	6	and	4	8½		
United States		3	0		4	8½	4	9
		4	10		5	0	5	6
		6	0	and	8	0		
Brazil		1 metre			3	6	4	0
		4	3		4	8½	5	3
		5	6					
Argentine Republic		1 metre		and	5	6		
Uruguay Republic		4	8½					
Chili		5	6					
Peru		4	8½					
Japan		3	6					

The term 'gauge of a railway' is generally understood to express the shortest distance between the inside edges

of the upper surfaces of the rails, but the word 'gauge' also applies to the instrument by which that distance is measured.

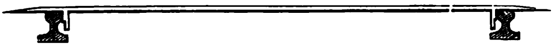


Fig. 7. Platelayers' gauge.

Each gang of platelayers has an iron standard measure or gauge of the proper distance between the rails, and it is the business of the foreman of platelayers to see that all parts of the line under his supervision are laid and are kept accurately to the standard. The measuring instrument or 'gauge' consists of an iron rod with a prong a short distance from each end, and is shown in fig. 7. The ends of the rod are flattened out, so that they will lie on the upper surface of the rails, and the distance between the outside edges of the upper part of the prongs is the gauge of the railway.

The wheels of railway vehicles are made with flanges, in order to prevent them from running off the rails, and the wheels are almost invariably attached rigidly to the frame of

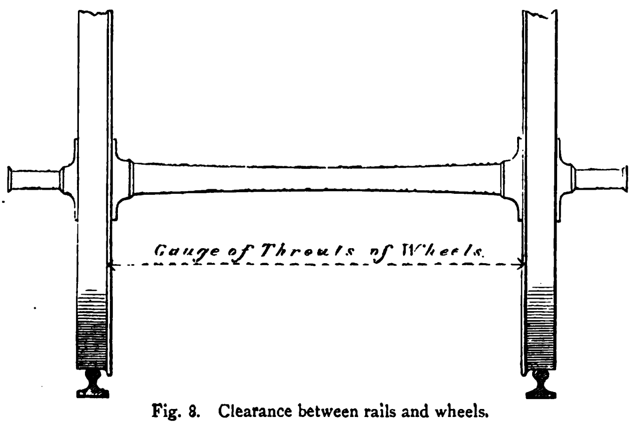


Fig. 8. Clearance between rails and wheels.

the carriage, and cannot adjust themselves radially to the curved parts of the line.

On plan a railway carriage going round a curve is seen

to be a rigid parallelogram, travelling between two concentric curved lines, and it is evident that if all the flanges were absolutely tight against the rails, and no play were allowed, carriages with more than two wheels could not be placed between the rails, unless their axles were radial to the curve.

To allow of the vehicles running round curves, the distance between the outside of the flanges of a pair of wheels (shown by the dotted line in fig. 8), or, as it is technically termed, the 'gauge of the throats of the wheels,' is made from $\frac{3}{4}$ to 1 in. narrower than the gauge of the railway. The difference of the respective gauges of the rails and of the wheels is called the clearance, and the wheels can and do move sideways on the rails, to the extent of the amount of clearance.

At switches and crossings the gauge of a railway is ordinarily made about $\frac{1}{4}$ to $\frac{3}{8}$ of an inch narrower than at other parts of the line, in order to lessen the sideways motion or play of the wheels of vehicles, and so to prevent their striking against the tongues of the switches or the points of crossings. A plate-layer's gauge has generally the measure or gauge for switches or crossings shown on it by a slight cranking of the prongs halfway of their height (see fig. 7), and thus the gauge at switches or crossings will only drop in between the rails as far as the cranking in the prong will permit, but in other parts of the line it will drop in as far as the top of the prong.

In laying or repairing a line of railway the gauge is placed so that the ends rest on the tops of the rails; the rails are pushed inwards till the two prongs are in contact with the rails, and the rails or chairs are then fixed in their position.

The general requirements of permanent way are that all its parts must be strong enough to bear without damage the heaviest loads which are to come on the line. The severest strains to which the line can be subjected are determined by the heaviest loads carried on any particular pair of wheels. In the case of lines worked by locomotives the heaviest loads

are on the driving wheels of the engine, as, unfortunately for the maintenance and renewal of the permanent way, the only way by which up to this time the power of the locomotive has been applied to the traction of trains is through the adhesion due to the insistent weight of the driving wheels on the rails. The weight on the driving wheels of large engines such as drag the Great Northern express trains is as much as 15 or 16 tons on a pair of wheels, or 8 tons on each wheel, when the engine is travelling steadily; and this may be much increased when the engine is lurching.

This great weight is most damaging to the permanent way; and efforts are made on most railways to get rid of the concentration of weight without giving up any of the tractive force due to the weight by distributing the weight required for adhesion over two, three, or four pairs of driving wheels coupled together. The system of coupling engine wheels has, however, many disadvantages, and it is a moot point whether it is less damaging to the permanent way than heavier concentrated loads carried on a pair of uncoupled wheels. A coupled engine does not travel so easily as an engine with one pair of driving wheels, and the slightest inequality in the diameter of wheels coupled together produces a detrimental action on both the wheels and the rails. Small inequalities of the road produce much more friction with coupled wheels than with single-wheeled engines, and thus what is gained by a reduction of concentrated weight is more or less neutralised by accompanying disadvantages.

It is much to be wished that some means may be found of applying the tractive force of the locomotive through all or through most of the wheels of the vehicles forming a train. If this could be satisfactorily accomplished, instead of the permanent way being exposed to strains from driving wheels supporting from 10 to 16 tons on a pair of wheels, it would have to bear little more than the strains due to the weights of the heaviest loaded trucks or carriages, which rarely have more than from 3 to 8 tons on a pair of wheels.

It would be difficult to estimate the saving which such a revolution might effect in railway working expenses.

That permanent way may be strong enough to bear without damage the heaviest loads which can come upon it, the following conditions should be complied with:—

1. The area of the sleepers bearing on the ballast should be large enough to avoid risk of their subsidence under the loads travelling over the line.

2. The bearing area of the chairs on the sleepers, or, if there are no chairs, the bearing area of the rails, should be large enough to avoid crushing of the wood and the consequent sinking of the chair or rail into the wood.

3. If chairs be used the bearing area of the rail on the chairs should be large enough to avoid damage to the underside of the rail.

4. The rail should be strong enough either in itself, or when assisted by longitudinal sleepers, to avoid deflection vertically or sideways beyond the proper limits of its elasticity.

5. The two rails forming a line of way should be so securely fastened that they cannot spread apart sideways, and play or slackness in the fastenings should as far as possible be avoided.

6. The rails should be connected endways so that the joints between them may be as nearly as possible of uniform strength with the rest of the line.

7. The material of which the rail is made should be such as will resist not only the strains due to the rail acting as a girder under a passing load, and the intense local pressure of the weight on a very small surface, but also the abrasion caused by the grinding or sliding action of the wheels on the surface of the rails.

8. The permanent way, considered as a whole, should be sufficiently elastic to 'give' a little under the passing loads, but in such a way that the several parts cannot work loose.

9. The vertical distance between the upper surface of the

rails and the supporting surface of the ballast should be as small as possible, in order that the leverage tending to disturb the permanent way on its bed on the ballast may be proportionately reduced.

These being the general principles to be aimed at in the construction of efficient permanent way, the several parts of permanent way in ordinary use have next to be considered. In so doing those forms of sleepers, chairs, rails, and fastenings, which are largely employed will be described, and no attempt will be made to deal exhaustively with the many meritorious modifications or inventions, which have been and still are being brought forward, but which have not been extensively adopted. Probably in no branch of industry have more patents been taken out than for improvements of the several parts of permanent way; little radical alteration, however (except in the fish joint), has taken place in the arrangement and designs which were originally adopted by the engineers of the earlier railways made in this country. All the parts have gradually been made heavier, to keep pace with the increasing loads which have been placed on railways, but permanent way now-a-days is very like permanent way of thirty years ago magnified in all its parts.

Ballast.

The Ballast, which is the foundation of the permanent way, and which is very commonly treated as part of the permanent way itself, will first be considered.

The formation level of a railway is generally about 2 ft. below the upper surface of the rails, and thus if the top of the ballast is (as is usually the case) about level with the under surface of the rails there would be a thickness of ballast of about 1 ft. 7 in. above formation level. A greater thickness of ballast is occasionally used in cuttings, for the purpose of providing more efficient drainage below the sleepers,

as water is more apt to accumulate in such positions than on the top of an embankment.

In hot dry weather the ballast is often heaped up against the rails on the side on which the wooden keys which secure the rails in the chairs are placed, in order that the ballast may partially cover the keys, and so modify the action of the sun in drying them, and causing them to shrink and to become loose in the chairs. The ballast in such cases also acts usefully in preventing any shrunken keys from shaking out of the chairs, which cannot take place so long as the ballast restrains the keys from moving endways.

Too much care can scarcely be given to the efficient drainage of the ballast. Any accumulation of water between the sleepers and the ballast on which they rest, or in the ballast generally, acts most prejudicially to the security and durability of the road, and may affect the stability of the earthworks. It is important that the ballast supporting the sleepers should be a hard material which can be readily packed under and round them, but it is at least equally important that it should afford an easy passage through which the water can run away from below the sleepers. If water is allowed to lodge underneath a sleeper, every time a train passes over it, the sleeper is pressed down, and the water is squirted up at the sides and ends of the sleepers. In such cases some kinds of ballast under continued attrition gradually become mud, and the sleeper subsides more and more as the process goes on. This action may at times be seen on railways, where either bad ballast has been employed, or where the side drains are inefficient.

Ballast should be composed of a hard and unfriable material, such as gravel, broken stone, broken bricks, hard burnt clay, or slag from blast furnaces, and great care should be taken to exclude from it dirt or soluble substances. If burnt clay is used—as is sometimes the case in localities where the other materials above mentioned are not easily to

be obtained—it should be burnt as hard as possible, so that it may not be crushed or become dusty under the weight of the trains. Hard broken stone or sound broken bricks are often too expensive to be used as ballast, from the first cost of the materials themselves as well as from the cost of the labour required to break them; but occasionally these materials are available, and, if they can be used, answer admirably.

One of the best materials is slag from blast furnaces, which is now extensively used on railways in the iron districts. Slag is generally allowed to run away from the furnaces in a red-hot and fluid state into iron boxes or moulds, in which it is cast into an exceedingly hard solid lump called a slag-ball. The slag-balls usually weigh 3 or 4 tons; and if the slag be required for road-making or ballast, these heavy masses of slag have to be broken up into pieces of suitable size, at a very considerable expenditure of labour. Of late years, however, a mode has been adopted, when slag is to be used for ballast, of allowing the red-hot slag to fall on to shallow trays mounted on an endless horizontal chain, which slowly brings each tray in its turn below the spout out of which the slag runs, and the pace at which the trays travel is so regulated as to allow each tray to be below the spout just long enough for it to be filled. The tray, full of slag, then travels away from the spout, cooling as it goes, and in about a minute a jet of water is allowed to fall on the still hot slag. The water further cools the slag and makes it brittle, so that when, at the end of its horizontal course, the tray turns over, the slag falls out of the tray and breaks into small pieces, of a size suitable for ballast. Slag prepared in this way is extremely well suited for ballast, and is perhaps the best material to be found. It is, moreover, a great advantage to the ironmaster to find a use and market for his slag, which until lately was worse than useless, causing him great difficulty and expense in finding places where it could be deposited.

The material, however, most generally used for ballast, is gravel, which answers its purpose extremely well when it is free from loam or dirt. On coast lines shingle from the beach is often employed, and forms excellent ballast. Care should, however, be taken that no great quantity of shells is mixed with the shingle, as they are likely to be crushed under heavy weights.

In many cases materials for ballast can be obtained of uniform quality, and composed of stones, at once suitable for the upper portions of the ballast, which have to be packed round and under the sleepers, and for the lower portions of the ballast, the object of which is to provide efficient drainage. Figs. 5 and 6 show such a description of material, there being no difference in those sketches between the upper and lower ballast. When, however, stone, slag, or bricks have to be broken, or where the gravel in its natural state contains stones which are too large for the upper ballast, the coarse and fine materials are separated the one from the other, the former being put into the lower half of the depth of the ballast used, and the latter into the upper half. The upper ballast would in such cases be composed of stones or fragments, each of which would not exceed 3 cubic inches in bulk, and would average about 2 cubic inches, while the lower ballast would be composed of stones or fragments of from 3 to 30 cubic inches.

The width of the top of the ballast beyond the ends of the cross sleepers is generally about 18 inches. Thus, the width of ballast for a single line of railway is, at the top 12 feet, for a double line 23 feet, for a treble line 34 feet, and for a quadruple line 45 feet. The slopes of the ballast at the sides are usually about 1 to 1, at which inclination good ballast stands well. Occasionally, in expensive cuttings, or where natural ballast is scarce, and where, consequently, stone or brick or slag has to be broken for ballasting the line, it is desirable to keep the width of ballast as narrow as possible. In such cases the necessity for side slopes is avoided

by packing the sides with large stones placed nearly vertically, so as to resemble a rough retaining wall, as shown in

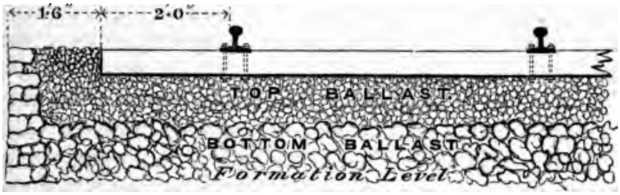


Fig. 9. Rough ballast packed at the side.

fig. 9. The width, depth, and slopes of the ballast for a line laid with longitudinal sleepers are usually much the same as those for a line with cross sleepers, but for light railways the ballast might be concentrated under the longitudinals.

Sleepers.

The sleepers of a railway (see figs. 5 and 6), serve to distribute the weights supported by the rails over the surface of the ballast. The materials employed for sleepers, are stone, wood, and iron. Stone sleepers, now very rarely seen, were much used in the early days of railways in this country, and possessed the great advantage of durability. They consisted of stone blocks measuring about 2 ft. square and 1 ft. thick, to which a cast-iron chair was attached by wooden trenails, driven into holes made in the stone. The blocks were placed about 3 ft. apart, from centre to centre, and though they answered their purpose fairly well, the disadvantages attending them were considerable. The stone being unyielding, there was great difficulty in keeping the chairs firmly attached to the stone; and, there being an entire absence of anything to act as an elastic cushion between the wheels of the vehicles and the ballast, a road laid with stone blocks was harsh to travel over, particularly at high speeds. Some of these disadvantages might, no doubt, be lessened; and in places where wood and iron are expensive, and where, on the contrary, stone

is cheap, and where the speed need not be high, stone sleepers should not be despised.

It was thought at one time that permanent way could not be made too rigid, and a short length of railway was once laid with wrought-iron rails in chairs firmly bolted down on a bed of solid rock. The result, however, was that in a short time the rails, chairs and fastenings, were seriously damaged. The parts of a railway and of the rolling stock are not made so mechanically accurate in shape nor so close fitting as to avoid a succession of more or less violent blows, and these blows act on the parts of any permanent way laid on a rigid unyielding bed like the blows of a hammer on any material interposed between it and an anvil, and quickly destroy it.

Wood is used for sleepers in three ways, viz. as cross sleepers (figs. 5 and 6, page 26), as longitudinal sleepers (fig.

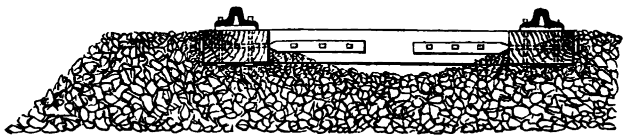


Fig. 10. Longitudinal sleeper road.

10), and in a combination of cross sleepers and longitudinal sleepers (fig. 11). The ordinary size of cross sleepers now

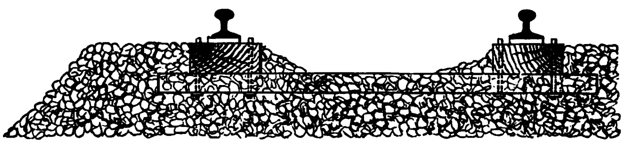


Fig. 11. Longitudinal sleepers on cross sleepers.

used is 9 ft. long, 10 in. wide, and 5 in. thick. The wood usually employed in England and in Europe generally is Dantzic or Memel fir, but occasionally pitch pine and oak are used; and both of these are, for this purpose, superior to fir; but the cost of them, as compared with that of fir,

is generally too great to permit of their being extensively adopted. In other countries many descriptions of hard woods, such as teak, mahogany and oak, are employed for sleepers, with the best results.

Sleepers should be of the soundest timber, with little or no sap, and they should be sawn true to form, at least at their lower side. Sometimes sleepers are allowed to be round at the top, and in this case a flat place has to be truly adzed or planed as a seating on which the chairs may firmly rest (fig. 12). It is far better, however, that sleepers

Fig. 12. Half-round sleeper.

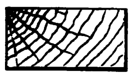


Fig. 13. Rectangular sleeper.

Fig. 14. Triangular sleeper.

should be cut out of trees large enough to permit of their being rectangular in section (fig. 13), and with little or no sap wood in the section.

Some years ago sleepers triangular in section (fig. 14) were used, with the advantage that in this way two sleepers of the required base could economically be cut out of a smaller log than if the sleepers were rectangular in section; but as it was found that more and more size and strength had to be given to sleepers under the increasing loads on locomotive driving wheels, and as the necessity for a thoroughly steady bearing surface for the sleeper in, as well as on, the ballast, became more and more apparent, the triangular sleepers were gradually given up.

Cross sleepers ought to be placed at such a distance apart as is proportioned to the area of the sleepers, the strength of the rails, and the loads to be carried. With the ordinary rails of 75 to 80 lbs. per yard, used in this country, and with the heavy loads on the driving wheels of English locomotives, the distance from centre to centre of cross sleepers of the ordinary size is generally 3 ft. and rarely

exceeds 3 ft. 3 in. On each side of the joints of the rails the sleepers are put closer together (2 feet apart from centre to centre), in order to afford extra support to the rail at its weakest place.

Longitudinal sleepers (fig. 10), as used in this country, are balks of timber, about 12 in. by 6 in., which are laid beneath and parallel to the rails, and give them a continuous support. The longitudinal timbers are connected at intervals by transoms about 4½ in. by 6 in. slightly notched into them, and secured to them by iron bolts passing through the longitudinal timbers, or by iron knees bolted to the transoms and to the longitudinal timbers. By means of the transoms and the bolts, the gauge of the railway is maintained correctly. Longitudinal sleepers are generally used in combination with a flat-bottomed rail, which is laid without chairs, and at the present time the use of the *nil* system is almost confined to the Great Western Railway and the broad gauge lines in the West of England. When the longitudinal timbers are of soft wood, thin pieces of hard wood, such as elm or oak, should be laid with the grain of the wood at right angles to the direction of the rail, between the rail and the longitudinal sleepers, in order to prevent the rail from being forced into the longitudinal timber, which is apt to happen when the grain of the wood is parallel to the rail.

The continuous bearing which the longitudinal sleeper gives to the rail is a great advantage in many ways, and it enables a lighter rail to do the work of a heavier rail. Thus on the Great Western Railway a rail weighing 62 lbs. to the yard has carried for many years, and is now carrying, the heaviest traffic, while other companies, and the Great Western Company itself, when using cross sleepers, use a rail weighing from 75 to 80 lbs. per yard. Apart from the saving of iron in the rails, the longitudinal system is safer than the cross sleeper road in the event of the wheels leaving the rails. In such an event, the wheels on the cross sleeper road drop into the ballast between the sleepers, and then

bump heavily over one sleeper after another, breaking the couplings and springs, and seriously damaging the carriages, while with longitudinal sleepers the wheels of vehicles which have left the rails can run, and often have run, along on the top of the longitudinal timbers comparatively smoothly, and without serious damage to the rolling stock, until the train has been stopped.

Against these advantages must be set certain drawbacks. The timber used for longitudinal sleeper roads must be of larger scantling (fig. 15), and therefore more expensive per cubic foot than the smaller timber used for cross sleepers. The longitudinal timbers are found more cumbrous than cross sleepers, not only in laying the road in the first instance, but what is of more importance, they are awkward in the ordinary repairs of the line. If a cross sleeper is damaged, or is found to be defective in quality, it is easily replaced without disturbing the rail or the adjoining sleepers; but in the longitudinal system, to replace the sleeper involves taking up the rail and the temporary stoppage of the traffic. The efficient drainage of the longitudinal sleeper road presents perhaps, some slightly greater difficulty than that of a road with cross sleepers. In the cross sleeper road the water can get away sideways at the spaces between the sleepers, while in the other plan the water is confined between the longitudinals, and has to be led away sideways through outlets made and maintained expressly for the purpose. There is no real difficulty, however, in this; and there is no reason why one system should not, with ordinary care, be as well drained as the other.

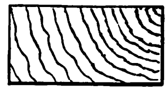


Fig. 15. Longitudinal sleeper.

On narrow gauge lines the longitudinal system involves an excess in the quantity of timber, but the reverse is the case on broad gauge lines, where the saving in quantity pays for the excess of cost in respect of the quality of the timber used. The sizes given above for cross sleepers and for longitudinal sleepers are those which have been found

best for the heavy traffic of this country; but where the loads are lighter the sleepers (as is the case with the other parts of permanent way) may be made of proportionately smaller dimensions.

Platelayers, in general, are averse to the longitudinal system, but then it is fair to remember that except on the broad gauge lines they have not much experience of its advantages and disadvantages. The disadvantages are moreover all in the way of difficulties, or rather inconveniences, in the maintenance and renewal of the line, which lie especially in the platelayers' department. The advantages are not so much from the platelayers' as from the passengers' point of view, and even here the advantage of extra safety in the case of a train leaving the rails is perhaps to some extent counterbalanced by the danger entailed by having to take up a rail whenever a timber requires renewal.

Sleepers fail, from rotting in the ground, from the chairs, or (in cases where there are no chairs) from the rails, being gradually driven into them, and splitting asunder the fibres of the wood, and, in many foreign countries, they are destroyed by white ants or other insects. As regards the first cause of failure, too much attention cannot be given to the drainage of the ballast, and even this is of little use unless the wood be sound and well selected. There are several chemical modes of treating wood, such as creosoting, kyanizing, or treating it with sulphate of copper, which increase its durability under moisture, and act as a protection against insects. In these processes the chemical preservative compound is forced by pressure into the pores of the wood. In creosoting as performed in this country the timber is put into an air-tight receptacle, and the creosote is forced into the wood transversely to the fibres. Great pressure is often necessary to effect this thoroughly, and it frequently happens that if the creosoting be carelessly done, the creosote does not penetrate to the centre of the log. In the sul-

phate of copper process, when it is carried out soon after the trees are felled, and when the natural moisture of the tree is still perfect a solution of sulphate of copper is forced in at the end of the log by hydrostatic pressure, and the solution driving the sap out before it, finds its way lengthwise of the fibres from one end of the log to the other.

There are several descriptions of iron sleepers used, especially in countries where timber is scarce or where insect life or atmospheric conditions renders the use of timber inadmissible for sleepers. The iron sleepers, which are almost always combined with the chairs, will be considered under the head of Chairs.

Chairs.

The rails first used on the horse tram-roads were flat plates, which were spiked down to longitudinal timbers. Subsequently a flat-footed rail was substituted for the flat plates, and this in turn gave way to the double-headed rail.

The introduction of the double-headed rail necessitated the use of some sort of support, to secure it vertically and horizontally in its proper position; for a rail of the double-headed section is by reason of its form deficient in stability, and cannot well be secured directly to sleepers by any bolts or fastenings passing through it. The appropriate name of 'Chair' was given to the support introduced between the rail and the sleepers; it fulfils the purpose of not only supporting and holding the rail, but also of spreading the weights carried by the wheels of vehicles over a considerable area of the sleeper. The double-headed rail being intended to be reversed, so that both top and bottom may be used in turn, it is necessary that the under and unused side should be kept as free as possible from damage until it is required to be turned upwards. Cast-iron chairs should fulfil this purpose, in addition to holding the

rail securely in its place. The rail is placed in the chair (fig. 16), and a wooden taper wedge or key is driven between the side of the rail and the hook-like side of the chair. Generally the wedge is placed on the outer side of the line of way,

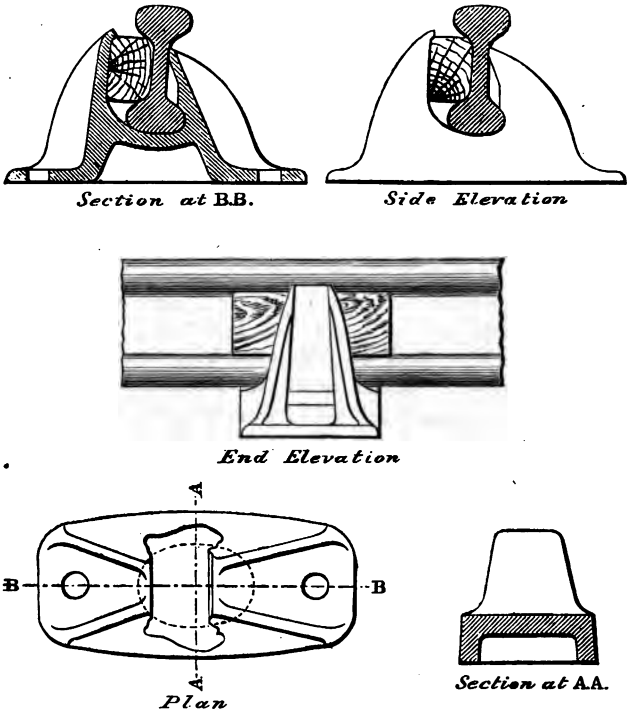


Fig. 16. Cast-iron chair for double-headed rail.

but on some railways it is placed on the inner side. The latter position is to be preferred, for should the wedges from any cause drop out of the chairs, the gauge of the railway, which in that case is determined by the outer jaw of the chair, and not by the key, cannot be deranged by the wheels forcing the rails outwards. Platelayers also, in walking along the

line for the purpose of examining the permanent way, can see the keys of both rails at once if they are placed on the inner side. Moreover if the wedges are on the inner side, the outside jaw of the chair can be carried up well under the shoulder of the rail, and unyielding lateral support be thus given to the rail near its top. Care, however, must be taken, in designing chairs, that the jaw of the chair (see fig. 17), or in the case of chairs with inside keys, that the key, be not placed so high as to get in the way of the flanges of the wheels. With reference to this point it must also be borne in mind that both the rails and the wheels wear away, and therefore allowance must be made for an extreme case of worn wheels running on worn rails.

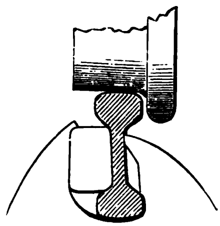


Fig. 17. Space for flange.

The wedge is intended to hold the rail firmly down on its seat in the chair as well as to hold it sideways in its position, it being of great consequence to check any rising and falling of the rail when the engine-wheels are passing over it. If the rail is free to move to a small extent vertically, the malleable rail, which is softer than the cast-iron chair, is hammered by continual blows from the wheel, and becomes indented to the shape of the seat of the chair. When such a rail is turned over, the surface is found to have abrupt depressions in it wherever it has rested on the chairs, and when traffic passes over the indented surfaces the wheels of the vehicles inflict a series of blows as they pass over the hollow places. An indented rail when turned is not only extremely unpleasant to travel over, but it also quickly wears out. So great is the difficulty of keeping the under surface of the rail uninjured, that some engineers have discarded the idea of turning the rails, and have made the double-headed rail with heads of unequal size, the smaller and lower one being only made large enough to give sufficient strength to the rail as a

girder, the rail not being intended to be reversed. In order to prevent the damage to the underside of the reversible rail, the chair has gradually been made to afford a greater bearing area, and has thus become larger and heavier; and whereas 20 lbs. used to be the weight of ordinary chairs, at the present time chairs weighing 50 lbs. are being laid down.

To avoid injury to the underside of the rails, chairs have been used, on the North Eastern and on some other lines, with a thin block or cushion of wood let into the seat or sole of the chair for the rail to rest upon. The wood preserves the rail, but it is said that it makes a somewhat loose road if not carefully attended to, from alteration in the bulk of the wood resulting from compression due to the weight or shrinkage due to atmospheric causes.

Another expedient was adopted in the bracket chair used on the West Cornwall Railway, the Llynvi and Ogmore Railway and other lines. This chair (fig. 18) consists of two distinct pieces of cast iron so shaped as to fit under the upper shoulders of the rail, and extending downwards about $\frac{1}{4}$ of an inch below the bottom of the rail. A wrought-iron bolt passing through the rail unites the two sides firmly together, and the chair is bolted or spiked down to the sleepers in the ordinary way on one side, while on the other side the bolt or spike passes through a slotted hole in the chair, the slot being at right angles to the direction of the length of the rail, and long enough to allow the half chair to be moved sideways about two inches. When a rail has to be taken out, the cross bolts are removed and the bolts in the slots in the

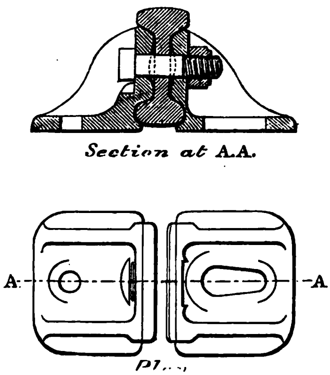


Fig. 18. Bracket chair.

half chair slackened. When this has been done, the half chairs on one side of the rail can all be moved away from the rail, the rail taken out and turned, or a new rail put in. This process would no doubt take a longer time than changing a rail secured in the chairs by wooden keys, and to that extent the bracket chair is inconvenient. A further inconvenience of the bracket chair occurs from the position of the chairs with regard to the rail being fixed, in consequence of the transverse bolts passing through the rails, whereas with the system of fastening with keys the chairs can be placed anywhere. The holes for the transverse bolt have to be punched or drilled in the web of the rail, and this is generally done at the rolling mill at which the rails are manufactured. Thus the chairs must be placed at those particular places, or new holes must be drilled. The position of the chairs can be accurately defined beforehand on straight portions of the line, but not so easily where points and crossings occur, as in such situations the sleepers are often placed wherever they can be conveniently got in. On sharp curves also some inconvenience results from the same cause, as in order to keep the sleepers radial to the curve the holes for the cross bolts have to be placed further apart in the outside rail than in the inner rail. These inconveniences are not of any serious importance, and may to a great extent be got rid of by foresight and management. They do not probably outweigh the undoubted advantages which the bracket chair possesses. These are, a great reduction in the weight of the chairs (the two half chairs weighing together only 18 lbs. and the bolt 1 lb. against the far greater weights of ordinary chairs given above), the reduction in the height of the rail above the sleeper by the thickness of the bottom of the ordinary chair, the consequent reduction of the leverage of the sideways strains on the chair, and on the ballast, the preservation of the lower surface of the rail from injury, and the saving of the cost and the avoidance of the many objections to the use of wooden keys.

Many varieties of design in railway chairs have been introduced and experimented on from time to time, to which it would be impossible to refer in detail. Speaking broadly, the chairs described above are those which are in general use, and which have stood the test of long practical experience.

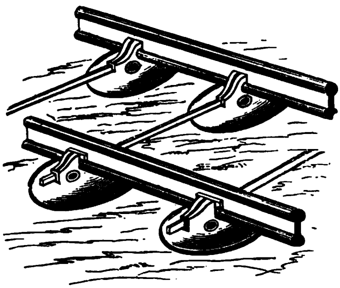


Fig. 19. Pot sleepers.

Under the head of chairs it is necessary to allude to the various descriptions of cast-iron sleepers which may be said to be both sleeper and chair in one. The best known of these are the bowl or pot sleepers (fig. 19), which are made of a domical shape of cast-iron, from $\frac{5}{8}$ in. to 1 in. thick, the bowl being about 23 in. diameter at its base, and about $5\frac{1}{2}$ in. high. Pot sleepers generally have the chair cast on them, the rail being fastened in the chair in the usual way with keys. In laying the line with pot sleepers, the ballast is made into little heaps where the sleepers are to be placed, large enough to roughly fill the interior of the bowls, which are then placed on the heaps; the final packing is effected by ramming fine ballast into the interior of the bowl through holes left in the upper surface of the bowl. The gauge is maintained by cross tie-rods attached to every pair, or to every other pair of bowl sleepers. The use of iron sleepers is advisable in countries where timber is scarce or exceptionally liable to destruction or decay; but the form of chair in which the fastening of the rail depends on a wooden key is, as has been already explained, objectionable in all cases, but more particularly so in hot climates, where pot sleepers are chiefly used.

A plan has been introduced of casting the bowls in an elliptical shape, with two jaws of a chair on one side, and a third jaw on the other side of the bowl, equidistant between the two opposite jaws (fig. 20). A key is driven be-

tween the rail and the centre jaw, which slightly bends, or springs, the rail, and the resilience of the strained rail keeps the key tight. This system has the advantage of affording a large amount of bearing for the rail on the bowl, but it has been suggested that the bending of the rail, although it is very slight,

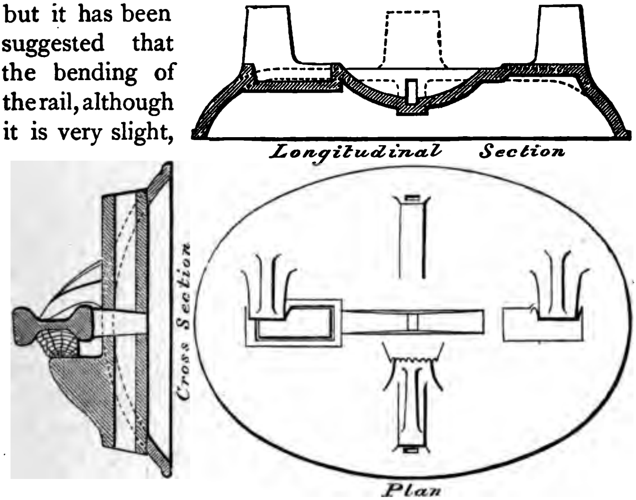


Fig. 20. Elliptical pot sleepers.

may be injurious to it. The pot sleeper may be made to carry a wood cushion on which the rail may rest; such an arrangement is shown on the left side of the plan and longitudinal section.

Sleepers have been made of wrought iron, following the general features of longitudinal or cross sleepers of wood, having chairs placed on them and secured to them by bolts; and the pot sleepers also have been made of wrought iron pressed to a form like the buckled plates often used for the platforms of bridges. The advantages of wrought iron over cast iron, in its greater strength and toughness, which render it possible to make the sleepers of equal strength with much less metal, are obvious, and the saving of weight

and consequent expense of carriage is often very important. But all these matters resolve themselves very much into questions of economy, and it is to be remembered that in order to compete with the first cost of cast-iron bowl sleepers, wrought-iron sleepers, owing to the greater cost of the material, have to be made extremely thin. They are thus likely to lose their form and consequently their strength; and in a material so liable to rust as wrought iron, oxidisation may cause serious difficulties, or may entail expense in endeavouring to guard against it.

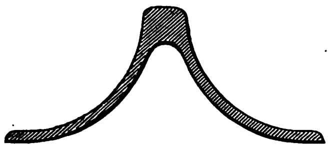


Fig. 21. Barlow rail.

The 'saddle-back' or 'Barlow' rail (fig. 21) was designed to dispense with sleepers and chairs altogether. The rail is laid directly on the ballast, and the ballast is intended to completely fill the inside of the saddle-back. The bearing area on the ballast can no doubt be made ample enough to support the loads coming on the line, but the rail, unless its two sides be held fast is vertically weak; while unless the ballast be kept absolutely tightly packed into the rail, the wings of the rail spread elastically, and, working in and out, gradually displace the ballast beneath them. The saddle-back rail has been largely used at home and abroad, and was thought at one time likely to form a very desirable and efficient description of road, composed of lasting materials with a minimum number of parts and fastenings, but experience has shown that so far at least as it has up to this time been used, it leaves much to be desired, and that it is not well fitted for high speed or for heavy traffic.

The late Mr. W. B. Adams urged the adoption of what is termed the 'suspended girder' rail (fig. 22), which appears to possess considerable advantages. He proposed to bolt continuous angle irons on each side of the rail of a width sufficient to give a proper bearing area on the ballast. The joints of the angle irons and of the rail

would be at different places, and not opposite to each other, and thus the joints between one rail and another could be made abundantly strong. The angle irons would give

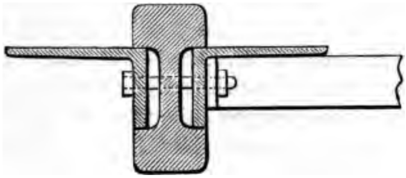


Fig. 22. Girder rail with wrought angle irons.

so much stiffness to the rail vertically and horizontally, that the web of the rail might be reduced in thickness, and thus with the same weight of metal in the rail, the rail itself might be made deeper, and consequently more stiff vertically under passing loads. Further advantages of this proposal are, that the support on the ballast would be given very near to the upper surface of the rail, thus diminishing the leverage at which the sideways strains act, and that the bottom of the rail could not be injured by indentation. Mr. Adams proposed to use timber balks (fig. 23) or cast-iron brackets (fig. 24) on each side

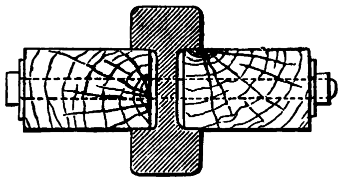


Fig. 23. Girder rail with timber supports.

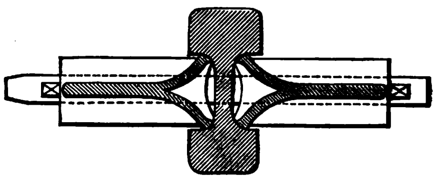


Fig. 24. Girder rail with cast-iron supports.

of the rail in cases where either might be found preferable to the wrought-iron angle irons.

Rails and Fish Plates.

There are, broadly speaking, two descriptions of rails used on railways, viz. the double-headed rail, shown in fig. 16 (p. 44), and the flat-bottomed rail, shown in figs. 25 and 26 (p. 53) and in figs. 27 and 28 (p. 54), and both descriptions are susceptible of considerable diversities of form. It is not necessary to describe minutely the various sections adopted by different engineers, but the general characteristics of each type will be described.

The double-headed rail is that which is more generally used in England, in France, and on the older continental railways. It was introduced upwards of forty years ago, and is still adopted for most new lines in this country, though elsewhere the flat-bottomed rail is often used in preference. The double-headed form possesses undeniable advantages. The metal in it is disposed very advantageously so far as vertical strength is concerned; the rails are easy of manufacture; they can be reversed, so that when one face is worn out the other can be used; and they can be efficiently connected at their ends.

On the other hand, this form of rail has little lateral stiffness, and requires extraneous sideways support. It possesses in itself but a small base, and requires chairs not only to support it vertically but also to spread the weight carried by it over a larger area than the base of the rail itself affords. These last two defects render it necessary that in using a double-headed rail the expense of chairs of some sort must be incurred, and the expense of these may be taken at from 250*l.* to 400*l.* per mile of single line of way. Against this considerable expenditure must be set the advantage of reversing the rail; but, as has been already explained, no thoroughly satisfactory means of keeping the underside of the rail uninjured have yet been found, or at least none which have secured the general approval of engineers, or have stood the test of experience for any considerable period. Any comparison of the two forms of rails must

thus be between a rail which cannot be reversed but which requires no chairs, and a reversible rail which must be supported on chairs, but which is generally injured before it can be reversed, and which rapidly wears out after being turned.

It is sometimes thought that chairs are a necessity for the purpose of securing all rails laterally, but general experience, particularly in foreign countries, seems to show that no real difficulty exists in thoroughly securing a flat-bottomed rail having a base of 5 in. or 5½ in. by fang-bolts passing through cross sleepers, and either passing through the flange of the rail, or holding it in some equally efficient way (figs. 25 and 26). On many lines flat-bottomed rails

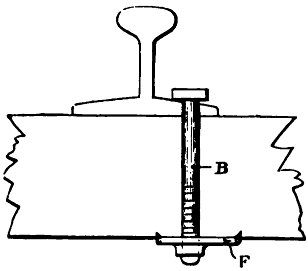


Fig. 25. Fang-bolt passing through rail.
B. Bolt. F. Fang.

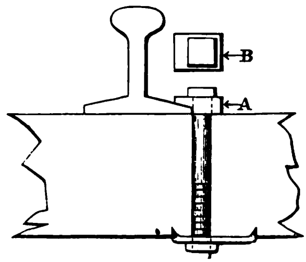


Fig. 26. Fang-bolt and clip.
A. Elevation of clip. B. Plan of clip.

are secured entirely by spikes or dogs (see figs. 44 and 47, pp. 71, 72), but this mode of fastening scarcely gives the rail a fair chance, and ought not to be employed when heavy weights are conveyed on the railway at high speeds. It is extremely difficult to keep spikes from slightly drawing out of the timber, and owing to the smallness of the transverse dimension of the rail as compared with that of a chair, play between the rail and the sleeper is more to be deprecated than the same movement between a chair and a sleeper. A common mode of fastening is to have two fang-bolts near each end of the rail, and to have spikes or dogs at the intermediate sleepers. Except on the score of economy, it is difficult to see why fang-bolts should not be used at all the sleepers, and the saving by using spikes or dogs is but small.

A good fastening consists of fang-bolts, with clips so shaped as to fit the upper surface of the foot of the rail (fig. 26). This plan obviates the necessity for making holes in the foot of the rail, which diminish the strength of the rail to a serious extent. In some experiments which were made, treating the rails as girders, on the comparative strength of solid rails, of rails with holes drilled, and of rails with holes punched of the same diameter, it was found that, taking the solid rail as unity, the strengths were as under—

Solid rail	1·00
Drilled rail	·68
Punched rail	·50

There seems therefore to be a great advantage to be gained by adopting a fastening such as that shown in fig. 26, which has the advantage of the fang-bolt without the disadvantages of holes in the rail. It is extremely desirable, other things being equal, to apply the fastening near the edge of the rail, so as to have as large a leverage as possible to counteract the tendency of the flanges of the wheels to thrust the rails over outwards.

The sections of flat-bottomed rails used are of two types: the first (fig. 27), which has been already referred to, and is shaped like a reversed T, often goes by the name of the

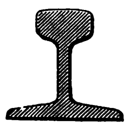


Fig. 27. Flat-bottomed rail.

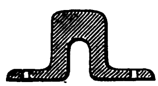


Fig. 28. Bridge rail.

'Vignoles' rail, from its having been extensively used by Mr. Vignoles, the well-known engineer; the second (fig. 28) is known as the 'bridge' rail, which will be described in detail further on; it was introduced by the late Mr. Brunel, and is largely used on the Great Western Railway and other broad gauge lines, with longitudinal sleepers.

The flat-bottomed Vignoles' rail differs from the double-headed rail in possessing in consequence of its wide foot greater lateral strength in itself to resist the outward thrust of the wheels without the support of chairs, while at the same time it possesses as much vertical strength. Some of the advocates of the flat-bottomed rail claim for it that it can be made stronger vertically than the double-headed rail, because, as it is not to be reversed, hard granular iron can be put in the head to resist compression, and tough fibrous iron in the foot to resist tension, while in a reversible rail the iron must be the same in both head and foot. This claim, however, cannot be allowed, as the rail acts as a continuous girder, and both the head and foot are alternately in compression and tension.

A very important question in comparing the two descriptions of rails is the bearing area on the sleepers afforded by each directly or indirectly: as the failure of wooden sleepers from the wood being crushed is one of the many sources of expense in the maintenance of permanent way. When the flat-bottomed rail is laid on cross sleepers, the bearing area is only the width of the sleeper multiplied by the width of the bottom of the rail. In this case the supporting area at each end of a sleeper 10 in. wide is rarely more than from 50 to 60 square inches, while with a chair the bearing area can be made as much larger as may be desired. If, however, the cross sleepers are accurately cut to fit the base of the rail, and the timber of the sleepers be good, the area of 50 square inches ought to be quite enough, more especially as the rail is laid crossways to the grain of the wood. In the case of some of the heavy chairs now being used, the supporting area is upwards of 100 in., but these chairs are probably made of this great size less for the sake of the sleeper than to preserve the under surface of the reversible rail.

The London, Chatham and Dover Railway was originally laid with flat-bottomed rails supported by small

flat cast-iron chairs (fig. 29): but this arrangement has not been approved, and is being replaced on the railway in question by double-headed rails and the ordinary chairs.

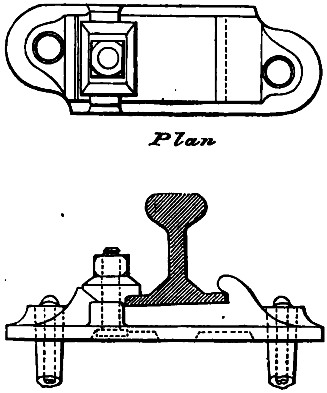


Fig. 29. Flat-bottomed rail in chair.

The top surface of a rail should be so designed that its shape will correspond to the shape of the tires of the wheels which are to run over it, so that the largest possible amount of supporting surface may be afforded to the wheel. The flat portions or treads of the wheels of ordinary railway rolling stock are not cylinders, but portions of cones, and the wheels are fixed to the axle, which revolves with them, unlike the wheels of road vehicles which revolve on a fixed axle.

The object of the conical form is that, when in passing round curves, the wheels are thrown outward by centrifugal force, the outer wheel may run on the rail where the diameter of the wheel is greater, and the inner wheel where its diameter is less. Thus, it was intended that although the outer and inner wheels should both revolve at the same speed the differences of length round a curve measured along the two rails should be represented by the different circumferences of the two wheels touching the rails. Whether this really takes place in practice or not is a point which will not now be discussed; but the fact remains that the wheels of railway rolling stock are almost invariably made conical, and it follows that it is desirable that the vertical axis of the rail should be placed at right angles to the surface of the cone. In a road laid with a double-headed rail, the chairs are therefore so made that when the rail is in the

chair it is in an inclined position (fig. 16, p. 44) to suit the inclination of the cone of the wheels, while when the flat-bottomed rail is used, the sleepers are adzed in the case of cross sleepers, or sawn or tilted in the case of longitudinal sleepers, to attain the same result.

The centrifugal force of a train passing round a curve tends to make the flanges of the wheel on the outside of the curve press against the rail on the outside of the curve with a force dependent on the speed, the curvature of the railway, and the weight of the vehicle. To counteract this effect the outer rail is elevated above the inner rail (fig. 30),

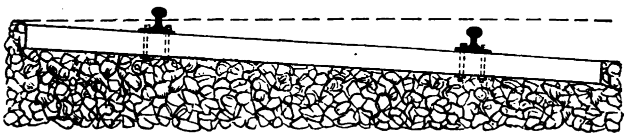


Fig. 30. Super-elevation of rails on curves.

and the amount of the super-elevation (which is the term generally employed) of the outer rail must be determined by the consideration of the maximum speed at which trains will pass round the curve. Thus the outer rails of curves near large stations, where all trains travel at a low speed, require little super-elevation, compared with the same curves between stations where the speed may be high. The rule for super-elevation usually employed is expressed by the formula—

$$E = W \frac{V^2}{1 \cdot 25\, R}$$

in which

W = Width of gauge in feet.
V = Velocity in miles per hour.
R = Radius of curve in feet.
E = Elevation of outer rail in inches.

When a sharp curve, say of 8 or 10 chains, joins a straight line, the necessary super-elevation of the outer rail is

considerable, amounting perhaps to 4 or 5 inches, and the full amount of super-elevation is required at the commencement of the curvature of the line. In such cases the rail on the straight portion of the line joining the outer rail of the curve has to be elevated above its opposite rail for some distance prior to the commencement of the curve, so that the proper amount of super-elevation may be attained at the commencement of the curve without too sudden an incline on the outer rail, which would injure the springs and impart a lurching movement to the carriages as they leave the straight part of the line and run on to the curve. In sharp reverse or S curves, it is desirable that a piece of straight line should be laid between the two curves, on which the super-elevation of one rail may die out and the super-elevation of the other rail may attain its proper amount. If the piece of straight line cannot be given, the junction of the two curves should be laid with check rails, which will be described below. But the proper plan in all cases where a curve joins a straight line or where two curves join one another is to ease off the one curve into the other or into the straight line by a 'curve of adjustment,' that is to say, by a change of curvature so graduated that the super-elevation of the rails not only varies gradually, but at the same time is also at each point suitable to the curvature.

On sharp curves an extra rail is often laid on the inner side of the inner rail of the curve (fig. 31), with only suffi-

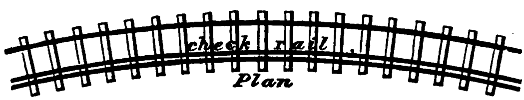


Fig. 31. Check rail on curve.

cient space left between the rails for the easy passage of the flanges of the wheels. The extra rail, which is called a check rail, relieves the sideways pressure of the wheels

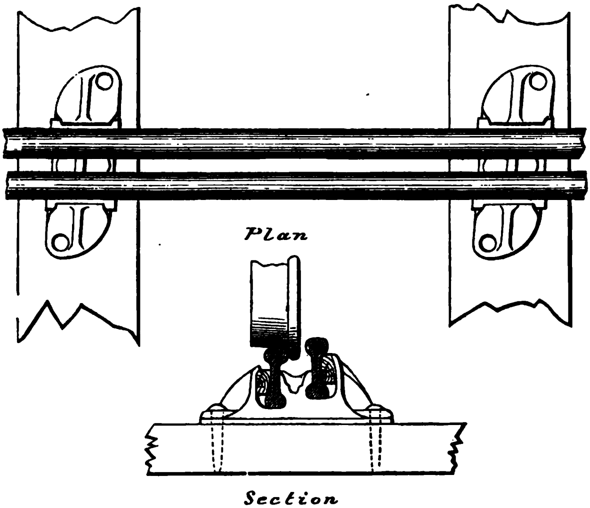


Fig. 32. Check rail with double-headed rail.

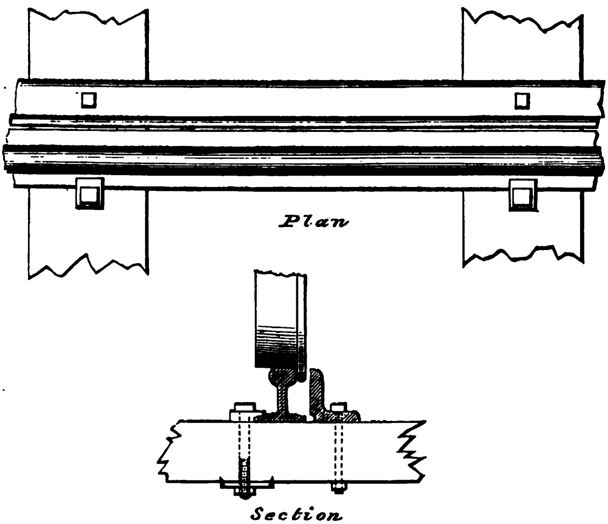


Fig. 33. Check rail with flat-bottomed rail.

against the outer rail, and prevents the wheels from mounting the outer rail.

The check rail, where the double-headed description of rail is used for the permanent way, is generally of the same section as the other rails, and is held in special chairs which hold both rails (fig. 32). Care should be taken that the distance-piece of the check rail chair between the two rails should be kept low enough to allow the flanges of worn wheels travelling on worn rails to pass over it without striking it. Where flat-bottomed rails are used the check rail is often composed of a strong angle iron firmly bolted down to the sleepers (fig. 33). As an additional precaution against the wheels mounting over it, a check rail is frequently elevated about 1 inch above the adjoining rail on which the wheels run (see section in fig. 32).

From the introduction of railways to the year 1847, rails were laid without any rigid connection between them endways. Prior to that time rails were simply placed one against another in a chair made of extra size for the purpose, and called a joint chair (fig. 34). Under such conditions the ends of the rails could slide up and down past one another to a small extent, and each wheel as it passed from one rail to another, having already depressed the rail which it was leaving, had to mount on to the next rail. which was not depressed as on to a slight step. Thus a series of blows occurred, and these blows naturally caused the ends of the rails to rapidly wear out. This action became more and more destructive as the weights of engines increased. In 1847 the system of uniting the ends of the rails by fish-plates was introduced, and it is now universally

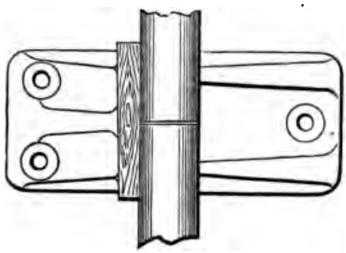


Fig. 34. Joint chair.

adopted. The object of the fish-joint (which derives its name from the nautical term 'fishing,' for mending a broken spar by lashing timber on each side of it) is that it should be impossible for one rail to rise above the other, and that the joint should be made as strong vertically as other parts of the rail, which would thus become a continuous girder. Joint chairs could thus be dispensed with, as the joint could be placed intermediate between cross sleepers. In the fish-joint (figs. 35 and 36) a plate of iron, called a fish-

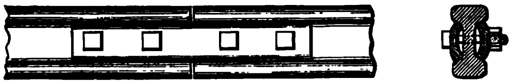


Fig. 35. Fish-plate for double-headed rail.

plate, which is about 1 inch thick, is placed on each side of the web of the rail, but not touching the web; the upper

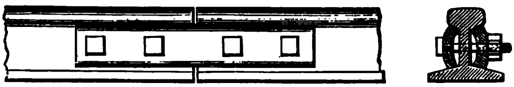


Fig. 36. Fish-joint for flat-bottomed rail.

and lower edges of the fish-plates are made to fit accurately the sloping sides of the head and foot of the rail, and bolts which are called fish bolts, passing through the rail, and the two fish-plates draw the plates together, and tighten the edges of the fish-plates against the rail. The rail at the fish-joint, though very strong, is, from want of depth of the fish-plate, not so stiff as other parts of the rail, and therefore the cross sleepers on each side of the joint should be brought nearer together than at other places, and the bearing reduced to as short a space as the length of the fish-plate will allow. To give extra vertical stiffness to the joint the fish-plates are sometimes made deeper than the rail and to project downwards below the bottom of the rail.

The efficiency of the fish-joint depends on the fish-plates being kept tight against the rail, but the nuts of the fish-bolts are apt to shake loose with the jar of passing trains, and

have frequently to be screwed up. To counteract this tendency as much as possible, the rubbing surfaces of the heads and nuts of the bolts should be made slightly concave, so that they grip the metal of the fish-plate near their periphery, and the thread of the screw should be at rather a flat pitch. The bolts cannot, however, be altogether prevented from getting loose, except by double or check nuts, which are an expensive expedient.

As the platelayers have constantly to examine the fish-bolts and to screw them up, it is desirable that in some way the bolt or the nut should be held firm and not be capable of being turned round, as otherwise, to screw them up, both bolt and nut must be held by spanners; fish plates have therefore been introduced of various designs to effect this purpose. In some of such arrangements one of a pair of fish-plates has square or oval holes instead of round holes, the fish-bolts having square or oval necks near their heads (fig. 37); other fish-plates have an indentation rolled in them into which the head or nut of the bolt fits, and is so held fast, while the other end can be turned; another arrangement is to have one fish-plate tapped with a screw to fit the fish-bolts, and nuts are then dispensed with.

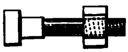


Fig. 37. Fish-bolt with square shoulder.

In all cases allowance should be made for the expansion and contraction of the rail from changes of temperature, by having the holes through the rail about $\frac{1}{8}$ of an inch larger than the diameter of the bolts, or by having the holes in the rails made oval in shape.

An elongated bracket chair, described above (p. 46), makes a good fish-joint for a double-headed or for a flat-bottomed rail, and with that mode of fastening the joint may be well placed over a sleeper. It is no doubt an advantage to place a joint over a support, and there can be no reason why it should not be done, provided that the joint be properly designed.

A description of flat-bottomed rail which has many

special characteristics is the Bridge rail, referred to above and shown in fig. 28 (p. 54). This form of rail was adopted by Mr. Brunel largely on the Great Western Railway and on its affiliated lines, and takes its name from the resemblance which the cross section bears to the elevation of a bridge with abutments and an arch spanning an opening. It was designed to be used in combination with the longitudinal sleeper, but has been laid in Ireland and Canada on cross sleepers, though it is not well suited for this latter purpose. The principle of the bridge rail is that it should possess a broad base and sufficient lateral strength, but that it need not have great vertical stiffness, as it was intended to be continuously supported on longitudinal sleepers. Thus, whereas a rail $4\frac{1}{2}$ or 5 inches high is found to be required with cross sleepers 3 feet apart, the height of the bridge rail used on the Great Western is only $2\frac{3}{4}$ inches ; and whereas the ordinary weight of rails now used on cross sleepers is from 75 to 85 lbs., the weight of the Great Western Company's bridge rail is only 62 lbs., even where their traffic is heaviest. Another reason why a lighter rail in the bridge form will do the work of a heavier rail, is that the edges of the rail (against which much stress comes from the flanges of the wheels) are admirably supported by the two vertical webs. An ordinary rail often fails from its overhanging edges being crushed and bent downwards, and a point which is therefore always aimed at in designing the form of the ordinary double-headed or flat-bottomed rail is to give as much vertical support as possible to the edges of the flanges. In the bridge rail there is no portion of the head overhanging the web, and thus the danger of unsupported edges giving way is avoided.

An objection which is often urged against the bridge rail is that there is a difficulty in uniting two rails endways in as satisfactory a way as is done by the fish-plates and bolts of the other two forms of rail. The ordinary fish-plates are not suited to the bridge rail, as they would get in the way of the flanges of the wheels, but there cannot be any real

difficulty in designing an efficient mode of junction, and probably the reason why it has not yet been carried out, is that with the longitudinal sleeper road the joints are not so weak as with the cross sleeper road, and the necessity of a better fastening than is now adopted has not been found imperative. The fastenings usually adopted for the ends of the bridge rail are shown in fig. 38, but they are manifestly inferior to the fish-joint.

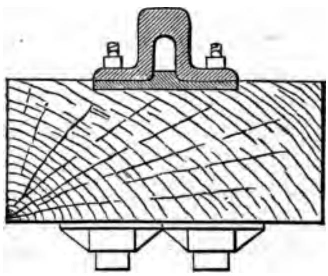


Fig. 38. Joint plates for bridge rail.

In the case alluded to above, in which the bridge rail was used in Ireland on cross sleepers, the rail was made nearly as high as an ordinary double-headed rail, and weighed 92 lbs. per yard. In that case a joint was devised, as shown in fig. 39. A centre rib is placed in the hollow of the rail, and the rib is supported and tightened up by two wedge-shaped clips, which are pulled together by cross-bolts.

As regards general principles governing the shape of rails, it must be borne in mind that rails are destroyed mainly by the rubbing and sliding of the wheels on the rails as distinguished from their rolling. This destructive rubbing is chiefly due to two causes. 1. That wheels of railway rolling stock are fixed to the axle. 2. That in almost all railway rolling stock the two or more axles of each vehicle must always remain parallel to each other.

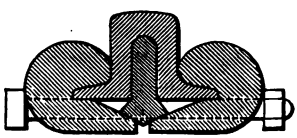


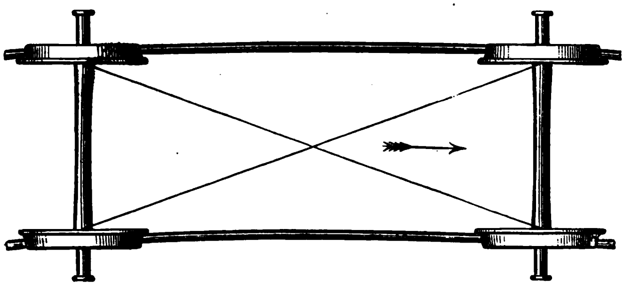
Fig. 39. Joint for bridge rail.

If two wheels of equal diameters are fixed to one axle and made to roll on a plane, as both wheels must revolve

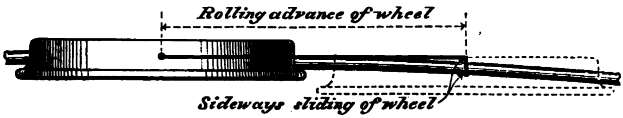
at the same pace, they must either both advance equally and the pair must travel in a straight line, or else one or other of the wheels must slip. In going round curves the path travelled by the outer wheel is longer than that travelled by the inner wheel, and it is obvious that with wheels fixed to the axle, unless their diameters are different, constant circumferential slipping must take place. The conical wheel was meant to obviate, or at least to decrease this evil, as the centrifugal force, it was thought, would push the wheels outwards from the centre of the curve, causing all the outer wheels to revolve on a larger circumference and all the inner wheels on a smaller circumference. Practically this remedial action takes place to a very limited extent; because, in consequence of the axles of carriages on railways being kept parallel to one another in a rigid frame, all the axles cannot adjust themselves radially to the curve, and when the leading wheels of a carriage are rolling forward and bearing sideways against the outer rail of a curve, the trailing or following wheels of the same carriage are rolling forward parallel to the leading wheels, and are bearing sideways against the inner rail (see fig. 40, p. 66). The evils due to the wheels being fixed to the axles are therefore not obviated by the conical wheels. The best form for the tire of a railway wheel is no doubt cylindrical, and the wheels, or at least one wheel on each axle, ought to be made to revolve on the axle, so that when a vehicle is travelling round a curve the outer wheel may revolve more rapidly than the inner wheel, and circumferential slipping be avoided. Fixing both wheels firmly on the axle no doubt simplifies carriage and engine building, and no great company has as yet used wheels loose on the axle except experimentally. It is much to be wished that the builders of rolling stock would turn their serious attention to designing wheels to rotate on fixed axles. The other cause of destructive rubbing is still more serious. In going round curves, as the axles in each vehicle remain parallel to one another, they cannot

set themselves radially to the curve, and consequently each wheel, instead of rolling tangentially along the rail, lies diagonally across it (see the enlarged plan in fig. 40), and as it rolls onward it has at the same time to be dragged or slid sideways on the rail, causing a very destructive abrading action on the rail.

The head of the rail is generally from $2\frac{1}{4}$ to $2\frac{3}{4}$ in.



Plan of two parallel axles with their wheels going round a curve.



Enlarged plan, showing the course of a wheel on a non-radial axle going round a curve.

Fig. 40.

wide, and the width of the head supporting the weight does not exceed $1\frac{1}{4}$ in., while the length of the rail directly supporting the weight, allowing for the compression of the rail and the flattening of the wheel tire, has been variously estimated at from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch. If the weight on a driving wheel be 8 tons, it is evident that the metal in rails is in this way subjected to a stress far beyond what would be considered prudent when iron or steel is used for other purposes, and it is not surprising that imperfectly made rails are absolutely squeezed out of shape. Indeed, what happens in practice is that the wheels squeeze and wear down the rails, till the rail-section approximates to the general *form* of the wheels. It must also be borne in mind

that wheel tires which have been long in use become hollow in the tread (fig. 41), and that any sideways movement of such wheels on the rail brings very small areas of surface into contact, and great local pressures are thus developed.

The edges of the head of the rail should be rounded off to correspond with the curve joining the flange and the tread of the wheel, and a radius of about ½-inch is ordinarily sufficient for this. The edges of the rail should be supported by making the sides of the head vertical down to the recess for the fish plates, as shown in fig. 27, p. 54. The upper and lower faces of the fish plates are usually made at the same inclination, and the angle generally adopted between the two faces is from 50 to 60 degrees.

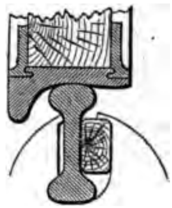


Fig. 41. Worn wheel tire on head of rail.

An important point is that the top and bottom of the rail be as nearly as possible of equal strength, considering the rail as a continuous girder, with the tensile and compressive strains due to the loads that are carried by it alternately exerted on the bottom and top flanges. Rails usually, however, wear out, not from the work they do considered as girders, but from the abrasion caused by the weight of the driving wheels sliding on them.

From the above considerations two things seem to be of great importance :—viz.

1. To reduce the weight on the driving wheels as much as possible.

2. To have as hard and homogeneous a metal for the head of the rail as can be given consistently with proper tensile strength.

Little is being done to carry out the first desideratum; indeed of late years the weights on driving wheels have on most railways been increased as greater tractive power is required. On the other hand, great attention is being given to the quality of metal used for rails; and both

engineers and manufacturers are constant in their endeavours to arrive at an admixture of metal and at a process of manufacture which shall carry out the second requirement above mentioned. Unfortunately, as the metal is improved, the increase of weight on the wheels seems to counterbalance the improvement.

These considerations naturally lead to the comparison of iron and steel as the material for rails; and in considering the distinctive characteristics of the two materials, the mode of manufacture of each must be borne in mind.

An iron rail is made by rolling together a number of separate pieces of iron, which, when placed ready for rolling, are called the rail pile. It is of much consequence in designing rails, or indeed any other form of rolled iron, that all parts of the section should be such as to be suitable to being rolled at one or nearly one intensity of heat. Great differences of thickness in the section are to be avoided as much as possible, for the heat which is suitable for the thick portions may be so high as to cause the thin portions to be unduly yielding, and *vice versâ*. A rail pile (fig. 42) is composed in different ways according to the specifications of engineers and the price of the rails. Speaking generally the pile is made about $8\frac{1}{2}$ in. wide, and 9 in. high, and if the rail to be rolled is a double-headed rail, it is built up as follows. The top and bottom of the pile which will hereafter form the two heads of the rail consist of slabs of hard hammered iron $8\frac{1}{2}$ in. wide, and $2\frac{1}{4}$ in. thick, and the space between the slabs is filled up with puddle bars $\frac{3}{4}$ in. thick, which may either be as wide as the pile, or may be put together so as to break joint. The pile is heated in a furnace to a welding heat, and hammered or rolled into a solid lump or bloom, about 5 in. wide, and 6 in. deep, which is again heated to a welding heat and rolled into the finished rail.

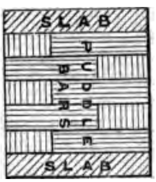


Fig. 42. Ordinary rail pile.

This mode of manufacture can never make a really homogeneous rail. It is not merely that the structure of the rail being made up of a number of plates requires a large number of welds to be made, but the top and bottom slabs are themselves the result of a similar process of hammering and welding, a process which begins from the time the iron leaves the puddling furnace. The efficiency of all these welds depends on the absence of any cinder in the iron, and on its being properly hammered at a proper heat. Even with the greatest care in manufacture wrought iron is a material the reverse of homogeneous, having fibres and a grain in it like wood. It is thus ill adapted for high transverse compressive strains and worse adapted for resisting violent rubbing, which can destroy it fibre by fibre. The rubbing resulting from the circumferential slipping and the sideways sliding of the wheels on the rails is, as has been said, the main cause of the destruction of the latter. It is true that wrought iron rails can be and have been made so well, in spite of the inherent defects of the material, as to stand the wear and tear of the traffic for very many years. Instances are well known of wrought iron rails having lasted upwards of twenty years, under heavy traffic; but in such cases the iron has been of a superior quality, and great care has been taken with the manufacture. Probably if such rails had to be made now, the price of them would not differ very materially from the price of steel rails.

Steel, as used for rails and properly manufactured, possesses most of the good qualities and none of the bad qualities of wrought iron. It has higher tensile and compressive strength, but above all it is homogeneous. The steel is fused into one molten mass, and then cast into ingots from which the rails after further hammering are rolled. There are thus no welds in a steel rail. The whole rail is of the same texture, and is not susceptible of lamination and destruction in detail. Care indeed is required, in manufacturing steel for rails, to avoid brittleness and to ensure tough-

ness; and it is to be borne in mind that in scarcely any material used for mechanical purposes are these qualities more dependent on niceties of admixture and manufacture. But no difficulty now exists in making thoroughly satisfactory steel rails; although when they were first introduced, and the delicacy of manufacturing steel was not appreciated, there was an uncertainty in the quality of metal which would be turned out from a casting.

The price of steel rails is now about 30 per cent. above that of iron, being at the present time (Dec. 1875) 9*l.* for steel against 6*l.* 15*s.* for iron, both of which are unusually low prices. On the other hand, the durability of steel rails may be taken as exceeding that of iron rails in the ratio varying from 6 to 1, to 4 to 1, according to the quality of the rails compared.

Under such circumstances, steel is evidently destined to supplant iron as a material for rails where the traffic is heavy; but where the traffic is light it is quite possible that the extra durability may be purchased at too dear a rate, when the compound interest on the first cost is taken into account.

One other variety of rails has not yet been referred to, viz. steel-topped rails. These are made by using a slab of steel instead of a slab of hammered iron for the top and bottom of the rail pile, or for the top only in the case of flat-bottomed rails. Some difficulty is found, from the difference in the welding heats of iron and steel, in thoroughly uniting the iron and steel parts of a steel-topped rail, and instances are known of a complete separation taking place between the two after the rail has been finished. This objection has been to some extent overcome by using steel slabs rolled in the channel form (fig. 43).

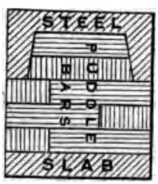


Fig. 43. Pile for steel-topped rail.

Steel-topped rails cannot, it is said, be relied on to have much more than half the life of solid

steel rails, and there is a further objection to steel-topped rails in the difficulty of disposing of or using the materials of the old rails. Worn-out wrought iron rails are generally cut up into suitable lengths, and are then used for the piles of new rails, but a difficulty occurs in so employing old steel-topped rails, as they consist of two metals whose welding heats and other qualities are different.

Fastenings.

Chairs or rails are attached to sleepers by spikes, trenails, wood screws, or fang-bolts.

Spikes (fig. 44) are cylindrical iron bars with heads and they are driven into a hole bored with an auger in the sleeper.

Fig. 44. Spike.

Fig. 45. Trenail.

The hole is made slightly smaller than the spike, which is retained in its position by the elastic grip of the fibres of the wood closing on the spike after it is driven, but spikes are at best apt to become loose from the yielding and shrinking of the timber. It is of great consequence that the chair should be held very firmly down on the sleeper, and that the spikes should accurately fit the holes in the chairs, for if they are even slightly too large the chair will be split, and if they be too small the chair will be loose on its bearing, and will gradually rub away and destroy the spike.

Trenails (fig. 45) are wooden spikes so compressed by machinery as to drive all moisture from them before they are driven into the sleepers. When they have been driven into their place their tendency is to swell by absorption of moisture, and they are thus held fast in their places. Trenails are, however, deficient in strength to resist the shearing action of the chair sliding on the sleeper. For this reason it is not safe to rely on wooden trenails alone, though they are no doubt well adapted for holding the chair firmly down on the sleeper. Where trenails are used now-a-days

spikes are generally used with them ; and if a railway chair is held down by trenails one at least of the fastenings should be an iron spike or fang bolt. A combination of spikes and trenails is in use, known as the hollow compressed trenail (fig. 46). This trenail consists of a hollow cylinder of compressed wood, and the centre of the cylinder receives an iron spike. The trenail is first driven into a hole bored in the sleeper, and then the spike, which fits the hollow in the trenail very tightly, is driven into the trenail. This further compresses the wood of the trenail and drives the fibres of the trenail into the fibres of the sleeper.

For fastening the flat-bottomed rail on to the sleepers, spikes which are rectangular in cross section, and which have large projecting heads extending about ½ an inch over the upper surface of the foot of the rail (fig. 47), are often used. These rectangular spikes go by the name of 'dogs,' or 'dog spikes.'

Wood screws (fig. 48) have been much used for holding

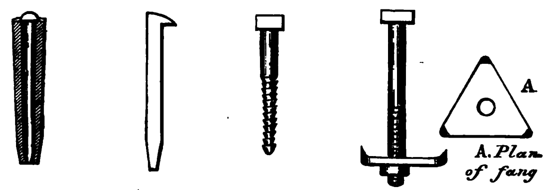


Fig. 46. Spike and hollow trenail. Fig. 47. Dog. Fig. 48. Wood screw. Fig. 49. Fang-bolt.

down flat-bottomed rails. These are screws of iron, with large cutting threads on them, and act like ordinary joiners' screws. An objection to them exists from their being weak in the thread compared with the neck of the screw where it passes through the chair, and from the fact that the screw is dependent for holding strength on the small quantity of wood included in the thread of the screw. The oxidisation of the screws is also apt to cause decay in the contiguous timber, and thus to make the screws become loose, in which *state* they are only equal to inferior spikes driven in decayed

wood. Wood screws used in hard wood sleepers are not so open to the above objections.

Fang-bolts (fig. 49) are the most thoroughly satisfactory mode of fastening. Fang-bolts consist of bolts long enough to pass through the sleepers, with a screw cut on the lower end to fit a wide flat nut, having on it fangs or short spikes, which embed themselves in the lower side of the sleeper and prevent the nut from turning round. When the head of the fang-bolt is turned round at the top, the bolt is screwed into the nut and draws the chair or rail firmly down on to the sleeper, and the elasticity of the wood of the sleeper keeps the bolt tight.

The means by which the double-headed rail is held in the chair is a wedge, or as it is technically termed, a 'key,' shown in fig. 16, page 44. The position of the key in the chair has been already discussed in pages 44 and 45, (see also page 34). The ordinary material for these keys is wood of hard description and good quality, which is generally compressed by hydraulic machinery until all moisture is driven out. When such a compressed key is driven into its position, it absorbs moisture from the air and expands, but in extremely dry weather wooden keys are apt to shrink and become loose in spite of the precaution of compressing them. Other descriptions of keys have been tried but not with sufficient success to supplant the compressed wooden key. A wrought-iron key and a spiral key (fig. 50) are examples of these modifications. A good key should hold the rail very firmly, but should at the same time be capable of being slackened when required. The compressed

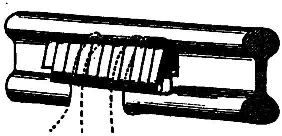


Fig. 50. Spiral key.

wooden key seems to fulfil these requirements better than either of the others above mentioned, but considering how extremely important it is that no movement should take place a wooden key is at best an imperfect contrivance for the purpose of holding the rail firmly in its position.

CHAPTER III.

POINTS AND CROSSINGS.

THE object of points and crossings is to enable vehicles to be transferred from one line of rails to another without the use of turntables or traversers. Points, which are also called switches, are movable rails, by means of which the direction in which a vehicle is travelling is changed, and crossings are gaps in the rails through which the flanges of the wheels can pass when a vehicle on one line of rails crosses another line of rails.

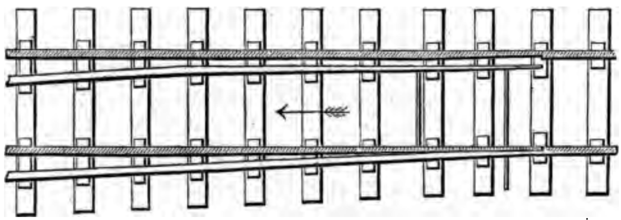


Fig. 51. Plan of a pair of points—the points standing right for the straight line.

Two drawings (figs. 51 and 52) are given of a pair of points, in the first of which the points are shown as standing right for the main or straight line, and in the second for a line diverging from the main line towards the left. It will be remembered that the wheels of vehicles are kept on the rails by the flanges, which project downwards on the inner side of the rails about an inch below the surface of the rails. Thus the wheels will follow the guidance of the rails, and in the sketches above, the path along which the wheels must in each case travel in obedience to the guidance of the flanges,

is shown by etched lines on the rails. The points or switches are rails pointed at one end, and of the same size as ordinary rails at the other end, where they are pivoted. The pivot end is called the heel of the points, and the heel is so placed as to allow room for the flanges of the wheels to pass easily between the heel of the point and the adjoining rail, which is called the stock rail.

One or other of the point rails is intended to be always against the stock rail; in the sketch above (fig. 51) the point-rail on the left of a train approaching in the direction shown by the arrow is against the stock rail; the train will consequently travel along the straight line, but if the point-rail on the right of the approaching train be against the stock rail (fig. 52), the flanges of the right hand wheels will rub against the point rail, and the train will be diverted to the left.

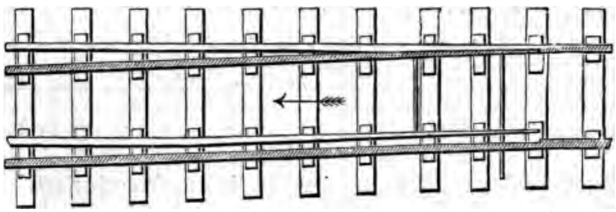


Fig. 52. Plan of a pair of points—the points standing right for the diverging line.

The ordinary length of points is 14 feet, and the abrupt divergence from a straight line which takes place in such a length, is more than twice as great as the tangential divergence which occurs in the same length on the sharpest curve in ordinary use on railways. Thus in the case of a pair of points laid in a straight line of railway it is of great importance that the speed should be low in passing over the points, when they cause a train to pass on the line diverging from the straight line, but when, on the contrary, the points are so placed as to cause a train to continue its course along the straight line, there is no necessity for a limitation of speed, provided that the points are accurately adjusted and

are held fast in their position. It is to be remembered also that from the construction of the points, and from the intersection of the different lines of way, little or no super-elevation can usually be given to the outer rail of the diverging line. The divergence between the thin end of the points and their heel is a fixed quantity, having to be always sufficient to allow the flanges of wheels to pass between the stock rail and point rail; thus, if, as is often the case at sidings and similar places, the points are made shorter than 14 feet, the rate of divergence is greatly increased thereby.

Below are sketches of what is called a cross-over road, which is a short diagonal line with a pair of points at each end joining two lines of rails together. The cross-over road is shown in two positions; in the first (fig. 53) trains would pass along the two straight lines, and in the second (fig. 54) a train which was being backed on either line

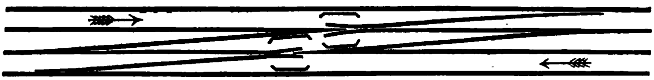


Fig. 53. Plan of a cross-over road—both pairs of points standing right for the straight lines.

would cross over from one straight line to the other straight line, along the diagonal line. The difference between these

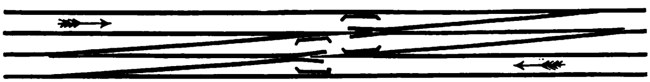


Fig. 54. Plan of a cross-over road—both pairs of points standing right for the diagonal line.

two sketches, it will be observed, is only that the ends or points of the diagonal line are altered in position.

When a pair of wheels has been guided on to the diagonal line, and continues to travel on the diagonal line, the flanges of the right-hand wheels will have to cross the rails on the left hand, or near side, of the straight line. This is effected by making a gap in the straight rail at least as deep as the projection of the flange below the tread of the

wheel, and to allow wheels on the straight line similarly to cross the diagonal line, a gap is required to be made in the diagonal line of rails. The intersection of the rails at these gaps constitutes a 'crossing,' and a sketch of one (fig. 55) to an enlarged scale is given below. In order

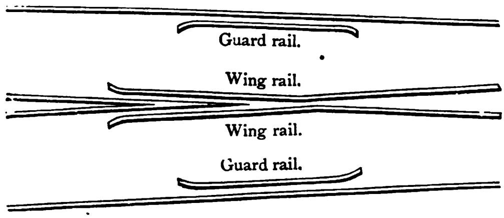


Fig. 55. Plan of a crossing.

that the flanges of wheels may pass with accuracy through the gaps, the wheels near the crossing and the opposite wheels are guided by what are called wing rails and guard rails, which are fixed near to and opposite the gaps, and acting as check rails which have been above described (p. 58), prevent the wheels from diverging to the right or left, and so passing through the gaps in the wrong direction.

The angle at which one line may cross another line varies with different positions and requirements, and the crossings may be made at any angle so long as the gaps can be properly protected with guard and wing rails ; that is to say so long as no wheel can run past a gap, unless at the same time the other wheel on the same axle is prevented by a guard rail from moving sideways. Subjoined are two cases of crossings (figs. 56 and 57), in the second of which it will be seen that the gaps in the rails are nearly opposite one another. When this is the case there is more risk of a wheel entering a wrong gap and so mounting the rail and leaving the line than at other crossings where one wheel only is engaged with a gap at a time. Wing rails are necessary to

guide wheels in approaching a gap, but they are sometimes omitted (see fig. 57) when the angle of the crossing is such that the wheels are sufficiently well guided by the guard rails

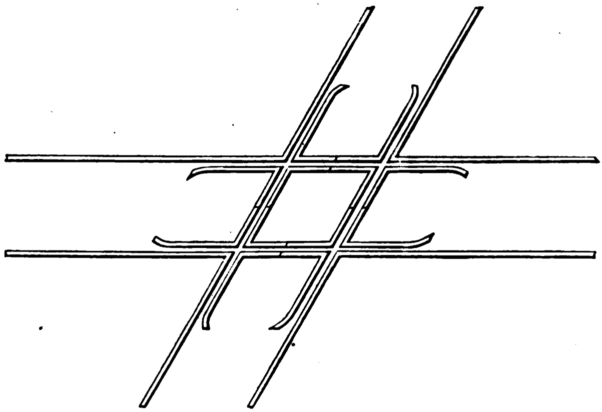


Fig. 56. Plan of a crossing with wing rails throughout.

before they reach the gap. It is perhaps best to have wing rails on both sides, as they steady the vehicles as a whole, and do not add much to the cost.

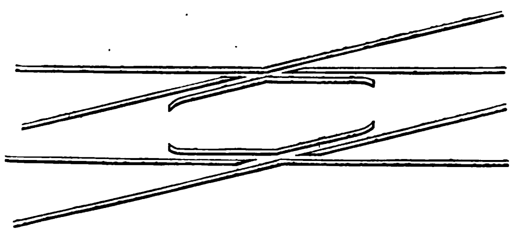


Fig 57. Plan of a crossing with wing rails on one side only.

The angle at which a junction or cross-over road may be laid depends upon the curvature of the main line, and on the amount of abrupt divergence from the main line, which may safely take place at the points as explained above. These two last considerations are governed by the nature

and speed of the traffic. In the case of a pair of points laid in a straight line, where high speeds are expected, the point rail is generally made 14 feet long, and the stock rail 16 or 17 feet long. The centre of the point rail at the heel of the points is about 4 in., measured horizontally, from the centre of the stock rail, and this allows $1\frac{1}{2}$ in. for the passage of the flange of the wheel between the two rails. The same amount of divergence is often given in a less length, and the points are made shorter than 14 ft. for positions where the speed is expected to be low, or where the main and branch lines are both diverging curves, in which case the two lines would from mere curvature diverge more rapidly than is the case with the longer points above mentioned, which are fitted for a line gently curved leaving a straight line.

The angle of the crossing of an ordinary cross-over road, joining two parallel straight lines, is about 1 in 10, in which case the cross-over road would be a reversed curve of about 10 chains radius. The length from the end of one pair of points to the end of the other pair of points of such a cross over road joining two straight lines 6 ft. apart, is about 175 ft., but where the two parallel lines to be joined by a cross-over road are not straight, the total length of the cross-over road and the angle of the crossings will depend on the curvature of the lines joined and on the minimum radius of curvature permissible for the cross-over road.

It is obvious that the end of the point and the end of the crossing, being necessarily weakened, in the one case by the small width of the point, and in the other case by the cutting away of the rail to leave the gaps for the passage of the flanges, must be exposed to high strains relatively to their dimensions. In this country points and crossings are now usually made of steel rails, and in order to give them additional strength, these rails, including the stock rail, are often made with the space between the flanges filled up on one or both sides; these rails are called filled rails, and a

section of one is given (figs. 58 and 59). The stock rail is often notched or cranked to receive the end of the point, so that when the point is against the stock rail there may be no projection against

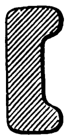


Fig. 58. Filled rail.

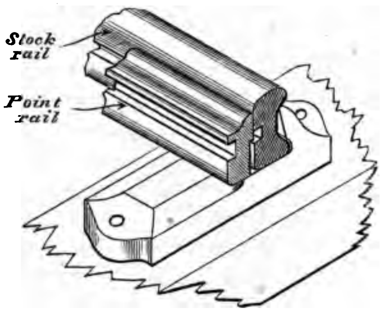


Fig. 59. Filled stock rail and filled point rail.

which the flange of a passing wheel can strike.

In other cases where the stock rail is not a filled rail, but a rail of the ordinary section, the end of the point is housed in under the flange of the stock rail (fig. 60), the extreme end being kept lower than the top of the stock rail, and below the level of the flanges of the wheels. In this way there is not so much necessity for notching or cranking the stock rail; and the extremity or thinnest part of the tongue of the switch is not exposed to any blows from passing wheels, for being below the level of the flanges, the wheels do not touch the point rail till they reach a part of the rail which is stronger than the extreme end could be made.

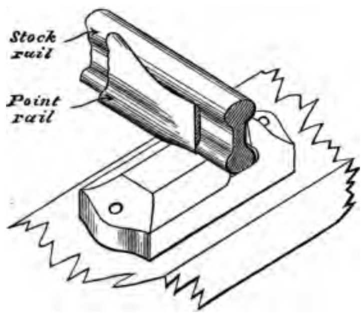


Fig. 60. Point and stock rail. Point housed below flange of stock rail.

In using all descriptions of switches, care must be taken that the point rails may be as stiff as possible laterally and be well and continuously supported laterally against

the stock rail; otherwise there is a danger of the sideways pressure of the flange of any wheel bending the point rail, and so springing open its extreme and thin end, in which case a succeeding wheel might strike it and mount the rail, or might pass on the wrong side of it.

The pointed end of the switch is so shaped that it may fit accurately against the stock rail, and when the point is moved over to the stock rail, the point rail and the stock rail are in contact for a considerable longitudinal distance measured along the point rail, indeed until the divergence of the two rails becomes greater than the width of the point rail. Where the point rail and stock rail do not touch each other, short studs projecting from the stock rail, and at a level below where they could be struck by the flange of a wheel, are fixed to the stock rail, to afford a lateral support to the point rail, and prevent it from bending sideways from the pressure of the flanges of the wheels.

Points at their thin end are made to move about $3\frac{3}{4}$ or 4 in., but it is only absolutely necessary that they should open about 2 in., and the larger space is adopted in order to avoid the possibility of the back of a wheel striking the end of the open point, in the event of the gauge being unduly wide.

If the points are not shut completely one way or the other, but are left half open, the wheels may run on both stock rails, and, (technically speaking,) 'get astride' on the points. Both the point rails in such a case would be between the flanges of the wheels, which, travelling on the diverging lines of the two stock rails, would leave the road as soon as the divergence of the rails was sufficient to allow the wheels to fall between them.

The two tongues of the points have to be rigidly connected, so that they may move accurately together, and that the horizontal distance between them may be properly preserved. The connection is made by cross rods, called connecting rods, shown in fig. 61, and there are ordinarily two connecting rods to each pair of points, which fit into

rings fixed to the points, about 2 ft. apart. It is of great consequence that the connecting rods should by no

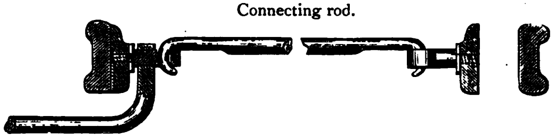


Fig. 61. Cross section of a pair of points and stock rails with connecting rod and point rod.

possibility become loose, or be detached from the points, as if one point were moved without the other any train passing over the points as facing points must be thrown off the line. The ends of the connecting rods are sometimes prolonged below the rings sufficiently to permit of a mortice being made in the rods, through which a split key is driven, as shown in fig. 62; but several other modes have been

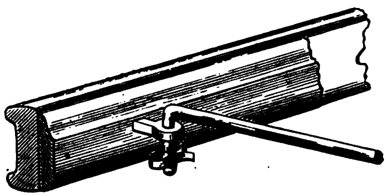


Fig. 62. Connecting rod with split key.

adopted on different lines of railway, to prevent the possibility of the connecting rods becoming loose. For the purpose of moving the points, one of the connecting rods is prolonged, or a separate rod, as shown above in fig. 61, is used, cranked beneath the rails, and rising so that it may be made fast to the point rail. This rod, by which motion is imparted, is called the point rod; it is extended horizontally to a safe position, and connected with a lever which is worked by the pointsman, when he wants to alter the position of the points.

The point rod is now-a-days usually prolonged into the signal-box, from which both points and signals are worked,

as will be explained hereafter in the chapter on Signalling. Indeed this arrangement is now required by the Board of Trade to be adopted on all new railways in the case of points connected with lines on which passenger trains travel. On old lines, and in goods yards, or similar positions, the points are often worked by a lever on the ground close to the points. Such ground levers are generally counterweighted, so that the points must by the action of the weight stand right for one line; and when it is desired to set the points for the other line, the lever must be used to raise the weight, which, when the lever is released, puts the points back to their original position. A disc or other signal is often attached to the lever as an indicator, to show which way the points are standing (fig. 63).

On the Great Western, and some other lines, there are no counterweights, and the point rod is frequently connected by a rack and pinion to a vertical rod working in an upright cast-iron pillar (fig.

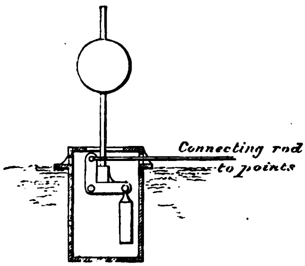


Fig. 63. Counterweighted point lever

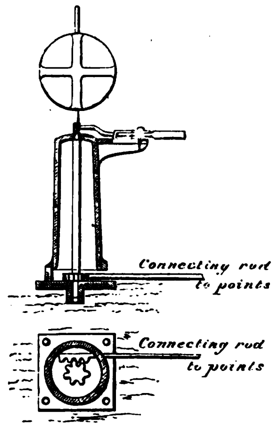


Fig. 64. Vertical pillar with horizontal point lever.

64) and actuated by a short horizontal lever between two guiding plates, which have holes in them corresponding with the two positions of the points. A disc and a lamp are placed on the top of the pillar, and move with the lever, so as to indicate by day and by night which way the points

are standing. When the vertical pillars (fig. 64) are not used a similar arrangement of guiding-plates and pins is applied, on the Great Western Railway, to the ordinary point levers, which are not counterweighted. In both cases when the points are placed right for either line, a pin is put through the hole in the guiding plates and secures the points in their proper position. This arrangement ensures at the same time that the points have been accurately adjusted, as otherwise the pin cannot be inserted.

In certain cases it is necessary that lines should diverge in two directions from one point, which is accomplished by what are called 'three throw' points (fig. 65), in which there are two

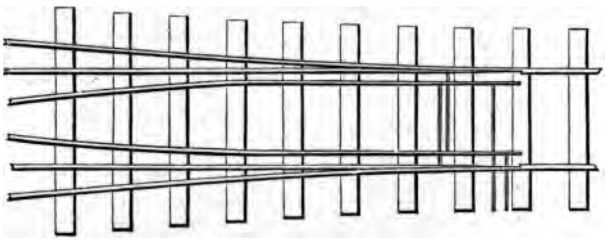


Fig 65. Plan of three throw points.

sets of tongues. Three throw points are rather complicated, and involve more abrupt divergence than ordinary points;

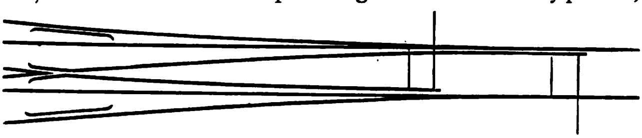


Fig. 66. Arrangement to avoid the use of three throw points.

many engineers prefer, therefore, the arrangement shown in fig. 66, in which the second pair of points is placed immediately beyond the heel of the first pair of points.

The tongues of switches and the ends of crossings are almost of necessity objectionably weak and rapidly wear out, while in order that the wheels of vehicles may pass over them properly, both points and crossings ought to be always

in most accurate adjustment and in perfect repair. Thus the points and crossings are critical parts of the permanent way, and require constant attention and frequent renewal. It is not too much to say that a large proportion of the mishaps which occur on railways, due to defects in the permanent way, are in some manner connected with the state of the points and crossings.

When the train approaches points from their heel or pivot end, they are called '*trailing points*'; but when points are approached by a train so that their thin end and not their heel is first touched they are called '*facing points*.' The same pair of points are thus called 'trailing' or 'facing' points according to the direction from which they are approached by a train. The construction of both is identical; the difference is the use to which they are put. Trailing points cause a convergence of traffic: facing points cause a divergence of traffic. Any error of working trailing points is not of much consequence, as in that case the flange of the wheel of the first vehicle as it advances from the fixed rail on to the movable rail moves the points into their proper position, if they have not been already so placed, and the succeeding wheels repeat the operation; it is thus obvious that whichever way trailing points stand, cannot affect the direction of the train passing over them, if the train can alter the position of the points to suit itself. Counterweighted points (fig. 63) are consequently often used as '*self-acting points*,' and are not adjusted by a signalman when they are to be used by a train as trailing points. If the points are not standing in the position suitable to the path of an approaching train, the train is left to put them into the proper position, which it does easily enough, though at the cost of some wear and tear on the gear of the point and counterweight, which is moved rapidly up and down as wheel after wheel moves the point rails sideways, antagonistically to the influence of the counterweight. This use of counterweighted self-acting trailing points presupposes that

the point rod is not held firm in either position, as otherwise the wheels of the train in forcing open the points would break the point rod or some other part of the mechanism. With modern signalling appliances (see chap. iv. p. 115), by which all point and signal rods are concentrated in one apparatus, and are held fast in both positions, the use of self-acting trailing points has to be abandoned.

In the case of facing points any want of accuracy in adjustment is most serious, as by merely moving the points 2 inches one way or the other the direction of a train can be altered, and if of two lines connected by facing points, one line be clear and the other line be already occupied by trucks or carriages standing on it, an approaching train can be directed either to safety or to destruction by this small amount of motion. Further, if the points be not properly adjusted, or be moved during the passage of a train over them, one part of the train may go on one line and one on the other. From the above causes many serious accidents have occurred at facing points, and every engineer avoids, as much as possible, inserting them on a main line. They cannot however be dispensed with altogether, as it would be impossible to conduct the present traffic of railways without them. But every effort should be made to guard against the dangers involved in the use of facing points, and to a great extent their inherent objections have been overcome by the appliances in connection with modern signalling apparatus, as will be explained in the next chapter.

The greatest care should be taken to keep the gauge of the line at points and crossings accurate, and constant attention is required to this matter on account of the strains to which these parts of a railway are exposed, in consequence of the unavoidable sideways pressure and blows caused by engines and carriages, as they pass over them. In order to avoid as much as possible the sideways motion and consequent blows on the rail, and for the reason referred to in the next paragraph, the gauge of points and crossings is generally

kept about a quarter of a inch narrower than other parts of the line, and (as has been stated in a former chapter), the plate layers are furnished with a gauge for points and crossings shorter than that for the line in general.

If the gauge of the line at facing points be wider than at other parts of the line, the danger of vehicles going on the wrong line is increased, and for these reasons. The gauge of the throats of even the new wheels of rolling stock, is, as explained above (page 29), usually from an inch to $\frac{3}{4}$ of an inch narrower than the proper gauge of the rails, and thus the tongue or thin end of that switch by which the direction of a train is changed, can be misplaced to that extent without encountering the flange of a wheel, supposing the wheels to be bearing away from the tongue and pressing sideways against the opposite rail. If in addition the gauge at the points be $\frac{1}{2}$ inch wider than the ordinary gauge of the line, the tongue of the switch could be further misplaced to that extent in addition to the clearance of the wheel, or to a total amount of $1\frac{1}{4}$ inch, without diverting that pair of wheels from the straight line; if the following pair of wheels instead of bearing away from the tongue of the switch, bore towards it, the flanges of these wheels might enter into the space of $1\frac{1}{2}$ inch, and be diverted along a different path to that which the former wheels followed, and most

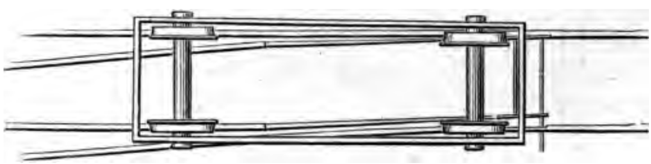


Fig. 67. 'Splitting a train.'

disastrous consequences ensue. This is sometimes called 'splitting a train,' and is explained by fig. 67. If, however, the gauge be tight, then even if the points have not been properly adjusted, the flange of the first wheel of a train will probably push the points home against one or other stock

rail, the succeeding wheels will keep them there, and the whole train will at least travel on the same line of rails.

The stock rails and the point rails are supported on chairs of special form. The chairs at the heel of the points, or immediately beyond the heel of the points, are made to hold the two rails, viz. the stock rail and the rail attached to the movable tongue, in one chair, as shown in fig. 68.

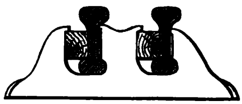


Fig. 68. Heel chair.

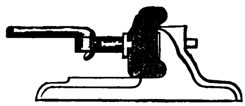


Fig. 69. Sliding chair.

The other point chairs (fig. 69) are made so as to afford a smooth surface, on which the tongue may slide freely backwards and forwards, and the stock rail is secured to the chair by bolts or studs passing through the jaw of the chair and the stock rail. The surface of the point chair should be kept clean and freely lubricated, to lessen the friction between the point rail and the surface on which it slides. The ballast should not be allowed to be higher than the upper surface of the sleepers in the immediate neighbourhood of points, or it may find its way between the stock rail and the point and prevent the point being accurately adjusted.

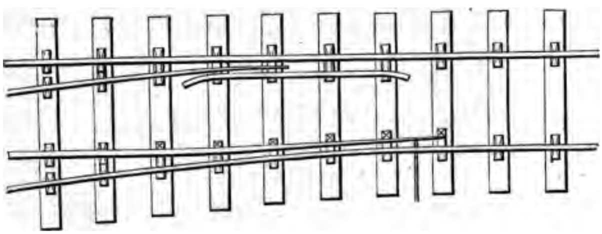


Fig. 70. Single tongued points.

Points are sometimes, though rarely, made with but one movable tongue, and a fixed point similar to an ex-

tremely sharp crossing, as shown in fig. 70, but this is not so good an arrangement as that of double-tongued points. The movable tongue is sometimes placed on the outside and sometimes on the inside of the curve diverging from the points. In the latter case, when the tongue is set right for the diverging line, as shown in fig. 70, it acts not as an ordinary point rail, but as a check rail (for fulfilling which purpose it is, from its thinness, not at all well fitted), and lateral support must be given to the tongue either by having inner jaws on the point chairs, or in some other suitable way. In this case of the tongue being placed on the inside line of the curve, the guidance given to the wheels by the back of the tongue to cause them to diverge from the straight line is more abrupt than is the case with double-tongued points, or when the switch tongue is placed on the outside line of the curve, in which cases guidance is given to the opposite wheels by the inner or proper side of the movable tongue on the outer rail of the curve. The extra abruptness of divergence when the tongue is on the inner line of the curve, is caused by the shape of the back of the movable tongue, which fits against the stock rail. As the divergence which takes place at even the best double-tongued points is very abrupt, any addition to the abruptness is a serious objection to the use of single-tongued points. On whichever side, however, the movable tongue is placed, there is a further objection to the single-tongued points, from their not affording so much support to the treads of the wheels as the double-tongued points give. It will be seen by fig. 70, in which the point is set right for the diverging line, that the treads of wheels on the outer line of the curve are not nearly so well supported, until they run beyond the fixed point, as they would be if a second movable point of the same length as the opposite point were substituted for the fixed point. To get over this difficulty when single points have been used, a casting is sometimes placed on the inner side of the rail which is opposite to the single

movable tongue at such a level that the flanges of the wheels may run on the casting, and so support the weight, instead of its resting entirely on the outside edges of the treads of the wheels.

The advantages of the single-tongued switches are a small saving in first cost, and perhaps some saving in maintenance, from there being fewer moving parts. The objections to their use, referred to above, overbalance their advantages, and they are but seldom adopted.

Chairs and sleepers at points and crossings are often put nearer together than in other portions of the line, on account of the weakness of the tongues and the extra wear and tear that necessarily takes place in such positions ; and instead of ordinary sleepers, through timbers of extra length are frequently used near the points and crossings. These timbers carry the four rails of the two lines of way for some distance from the points, and hold them all firmly together in their proper relative positions.

Crossings are made in various ways. One mode, which was much used in the early days of railways, and is still employed, is to cut two ordinary rails and join them together by bolts or rivets. Another method is to join the rails together by welding. A third is to have a solid forging for the apex of the crossing, with means for joining ordinary rails to the forging by fish plates. Steel has been found the only satisfactory material for resisting the wear and tear of crossings, and rails which are used in crossings, are in this country generally made of solid steel. Sketches of crossings made out of rails have been given in figs. 55, 56, 57; pp. 77 and 78. Cast steel crossings (fig. 71) are also largely used, either reversible or flatfooted. These crossings are cast in one piece, long enough to ensure steadiness, and occasionally the groove in them is made so shallow opposite the apex of the crossing that the flanges take a bearing on the bottom of the groove, and so relieve the intensity of the pressure of the treads of the wheels on the narrow surface of the

apex. This plan is not found satisfactory, because of the uneven wearing of the treads of the wheels, which often causes the flanges of worn wheels to be nearly an inch deeper than the flanges of new wheels, and it is better that the grooves should be deep enough to allow all flanges to pass without touching the bottom of the groove. Solid crossings

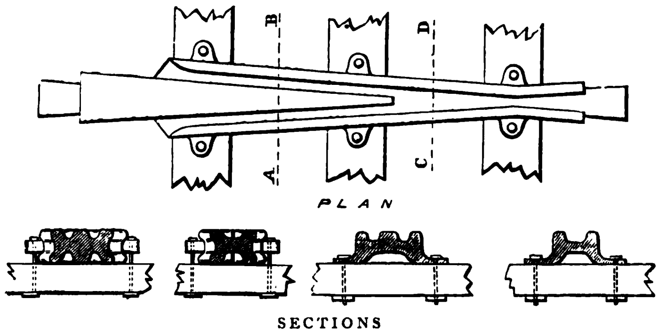


Fig. 71. Cast steel crossings.

have great advantages in durability, and in steadiness, when made long enough and carefully bedded. The sketch (fig. 71) shows different sections of cast steel crossings, of which one is reversible and the other is flatfooted. The reversible crossing is used with or without chairs, but there is some little difficulty in keeping it steady without the help of chairs.

Slip points, which are shown in fig. 72 in the two positions in which they can be placed, are points giving access

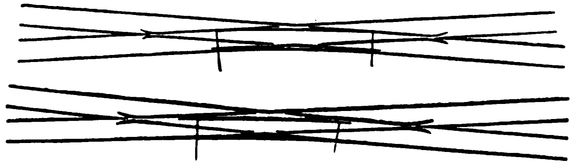


Fig. 72. Single slip points.

to a very short line which connects together a line of rails crossing another line of rails in such a way that the slip

points at each end of the short connecting line and the connecting line itself are introduced between the extreme points of intersection of the two lines, and the short connecting line does not itself cross either of the other two lines. Slip points have the advantage that they do not entail any additional crossings, but they can only be introduced where the angle between the two intersecting lines is such that the curve of the connecting line which is tangential to both crossing and crossed lines at the connecting points, is not too sharp. There must be space between the two intersecting lines opposite to the ends of the slip points, sufficient to allow the ends of the points to be moved $3\frac{1}{2}$ inches away from their stock rails without interfering with the adjacent line.

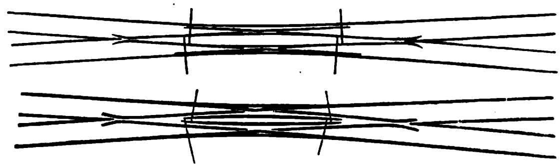


Fig. 73. Double slip points.

Double slip points (fig. 73), which also are shown in two positions, are of the same description, and serve to connect the two intersecting lines in both directions.

Safety points (fig. 74) are points leading out of a siding

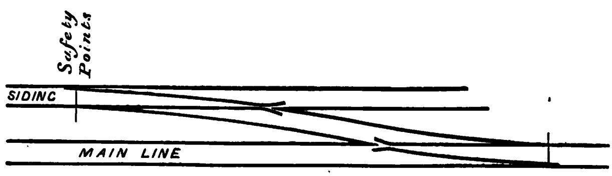


Fig. 74. Safety points.

with either no rails or else with only one or two lengths of rails joined to the heel of the points, and their purpose is to prevent a train or single vehicles from leaving the

siding without the overt act of some one in charge moving the points. Safety points are weighted or locked so that they stand normally in the opposite position to that which they would occupy if a train were being directed from the siding to the main line. Thus, if a truck should be blown along the siding by the wind, or if an engine-driver start his train without orders, or if anything is being shunted on the siding without permission of the signalman in charge of the main line, and without his setting the points right for vehicles leaving the siding and going on to the main line, the vehicles run over the end of the dummy rails, and imbed themselves harmlessly in the ballast, but do not run on to and foul the main line. Sometimes safety points are joined on to a short subsidiary siding terminating with buffer stops or in a heap of earth, so that vehicles may be brought up against that obstacle instead of running off the line into the ballast.

Safety points are also occasionally used on steep inclines to guard against the danger of the couplings of goods or mineral trains breaking as a train is ascending the incline, and the detached trucks running by gravity down the incline, and coming into collision with any other train following the train from which they have broken away. In such a case the safety points are weighted trailing points for trains ascending the incline; and their normal position is that of facing points to divert from the main line the runaway trucks, which would of course be travelling in the reverse way to that which is the proper direction of traffic. Safety points in such a position ought not to be left unguarded by a pointsman, as serious accidents have happened in consequence of an engine or train being sent intentionally, but in forgetfulness of the existence of the safety points, on the wrong line in a case of emergency (as perhaps during some temporary disarrangement of the traffic), when the safety points are met as facing points, and the train so travelling on its wrong line is turned to destruction.

The present form of points and crossings was not adopted

till long after the introduction of railways. The original mode of providing for trains crossing from one line to another was what may now be seen on most temporary railways, such as those used by contractors. In this method (fig. 75), the four ordinary rails of the two diverging lines

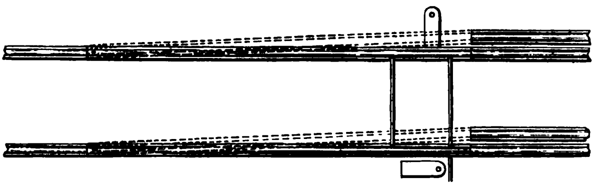


Fig. 75. Contractors' points.

are brought as close together as the space necessary for the flanges of the wheels will allow, and the two rails of the single line from which divergence is to be given, which are rails of the ordinary description, and not thin specially shaped point rails, are pivoted, so that their free ends can be placed opposite the ends of either pair of the diverging lines. The exact amount of movement is regulated by a lever, and the movable rails are kept fast by pins dropping into holes in the rails and into the sleepers, or by a hinged catch on the sleepers.

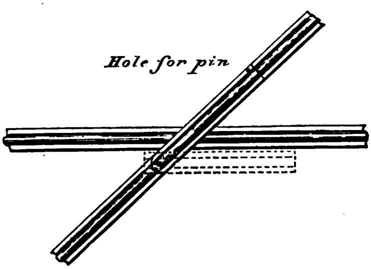


Fig. 76. Contractors' crossing.

In the case of the old form of crossings which are still used on temporary railways, the rails are not cut for the flanges to pass, but one rail is elevated sufficiently above the other to allow it to cross over the top of the lower rail The higher rail is pivoted so that it can be moved out of the way when traffic has to pass along the lower rail (fig. 76). This description of

crossing has the disadvantage of requiring to be moved every time a train passes along the lower rail, and it cannot compare in convenience with the present system, nor is it adapted to the complications of many lines intersecting one another. The old-fashioned form of points and crossings possesses, however, an undoubted advantage as compared with the thin tongues of the points and crossings now in use, in that the rails are unweakened. The objection to the old form of points lies in the necessity they entail of a discontinuity between the ends of the movable and fixed rails; but if this objection could be removed by the joint being properly secured and made as strong as other joints on the line, this description of points would be superior to the modern form, especially in the case of those facing points over which trains have to travel at high velocities.

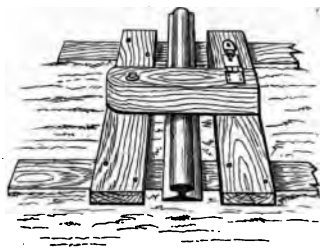


Fig. 77 Scotch.

Scotches (fig. 77) are used on sidings to prevent vehicles from being blown or being in any way unintentionally moved off the siding on to the main line. They are blocks of wood which either turn on a pivot or slide between guides over the top of the rail, and present an obstruction over which the wheels of vehicles cannot pass. They can be secured by a padlock, as shown, to prevent their being tampered with.

CHAPTER IV.

SIGNALS.

SIGNALS are the means by which instructions are given to the engine-driver or other person in charge of a train, in order to regulate the progress of the train from place to place.

It is thus of the most vital consequence that signals should be unmistakable, and that they should convey only such instructions as are proper to be observed, and as will, when obeyed, ensure the safety of the train.

It is proposed in the first instance to deal with the 'out door' signals which are exhibited to the engine-drivers and guards without discussing the reasons for such signals being given. There are in addition signals used for conveying instructions between different signalmen, which are now-a-days generally worked by electricity, and these will be referred to in a subsequent chapter.

The 'out-door' signals given are always two and often three in number. The two signals which are always employed are 'All right,' or 'Proceed,' and 'Danger' or 'Stop;' a third and intermediate signal is sometimes given to signify 'Proceed cautiously.' The mode originally adopted, and indeed still in use on some lines, for signalling trains is as follows: Signalling stations were erected at suitable places, such as at stations or junctions, and no train was allowed to pass any signalling station until the previous train had passed for a definite time, say ten minutes, during which time the 'Danger' signal was exhibited. When a train had left ten minutes a cautionary signal was exhibited to any following train, and this indicated to the driver that a train had passed

but from ten to fifteen minutes previously, and that it behoved him therefore to proceed cautiously. The 'Caution' signal was continued for perhaps another five minutes, and then the 'All right' signal was given, which therefore told an engine-driver that the previous train had passed at least fifteen minutes previously before he came to the signals. The intervals of time varied in different places with the exigencies or peculiarities of the traffic.

The third signal is being now to a great extent discarded. It was useful so long as efficient signalling inferred the preservation of an interval of time between trains as they passed any given place. Since the employment of the electric telegraph in working railways, the object aimed at in signalling is to preserve not an interval of time, but an interval of space, between trains. So long as the latter is preserved, no collision can take place, but the attempt to maintain an interval of time between trains is illusory. Between one signalling station and another an engine may break down, or the train may be in many ways prevented from running accurately to time; and thus, though all the time signals may have been correctly exhibited and a proper interval of time may have been observed at a signalling station between any train and the train following it, yet before the first train reaches the succeeding signalling station the second train may have caught up the first and have run into it.

With the present system of communication by telegraph between signalmen, each line of rails of a railway is divided into telegraphic districts, and it is a rule that no two trains shall be on one district or division of the same line of rails at one time. The system by which this is carried out is called the 'Block System,' and will be referred to in detail in chapter V.; but in connection with it only two signals need be given to an engine-driver, that is 'All right, Go on,' for the line is clear as far as the next station; or 'Danger. Stop,' because a train is already in possession of the particular division on which the train is desirous of entering.

In this way the fact that trains travel at various speeds becomes of little consequence, and the simple question to be signalled is whether a particular division of the line is occupied or unoccupied when a train desires to enter on that division.

When railways were first opened in this country, and the trains on each line of rails were few, there were either no signals at all, or signals of a very rough description. The signals were given in daylight by flags, or by a man holding up his arms, and at night by handlamps. These signals, which are called 'hand' signals, remain still in use, particularly in shunting, and the mode by which they are given is as follows. The 'All right' signal is given in daylight by a white flag or by holding the arm horizontally, as in fig. 78, and at night by showing a steady white light from a hand lamp. The 'Caution' signal is given in daylight by a green flag, or by holding an arm straight up, as in fig. 79, and at night by a green light. The

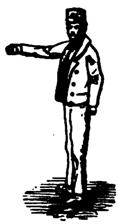


Fig. 78. 'All right' or 'go on.'

Fig. 79. 'Caution.'

Fig. 80. 'Danger' or 'Stop.'

Hand Signals.

'Danger' or 'Stop' signal is given in daylight by a red flag, or by holding up both arms vertically, as in fig. 80, or by waving a cap, flag or other object violently. At night the 'Danger' signal is given by a red light, or (in the absence of a red light) by waving violently any other light across the line. As the traffic increased, a better system of controlling the movement of trains became a necessity, and

signals fixed to posts by the side of the railway came to be universally adopted.

The type of fixed signals originally used on the various railways in England differed according to the ideas of each engineer, and to such an extent that in some cases a signal which indicated 'All right' on one railway denoted 'Danger' on other railways. The sketches (figs. 81 to 84) show a few of the different signals originally used on well-known railways, and some of them are still at work. Fig. 81 shows the signals introduced on the Liverpool and Manchester Railway about 1834. Fig. 82 shows the Grand

EARLY SIGNALS.

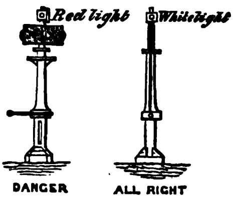


Fig. 81. Liverpool and Manchester Railway.

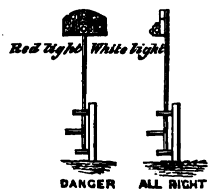


Fig. 82. Grand Junction Railway.

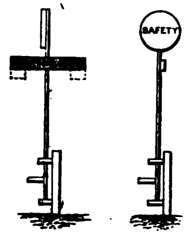


Fig. 83. Great Western Railway.

Junction Railway signals, first used about 1838. Fig. 83 shows the Great Western Railway signals, which were put up when the line was opened, and are still in use. The Great Western signals possess the advantage of being positive in both the signals given; that is to say, 'All right' is indicated by the exhibition of a disc and not merely by the absence of a prohibitory signal, and 'Danger' is indicated by the disc being made invisible, and by the exhibition instead of a horizontal board which is fixed at right angles to the plane of the disc, and on the same spindle. The up and down danger signals are distinguished by the up signals consisting of the plain horizontal board, and the down signals having vertical tails (indicated by dotted lines on the figure) to the ends of the horizontal board. Fig. 84 shows the London and South Western Railway signals in-

vented about 1840, and still in use. In these signals the exhibition of the disc indicates 'Danger' and not 'All right,' as on the Great Western Railway, and the absence of a signal means 'Proceed.' The disc is peculiarly made, one half only being solid, and it is pivoted horizontally at its centre so that it can be turned round by means of a cord passing round the edge of the disc and down the signal post, while the signal post itself is pivoted on a vertical pivot. When the solid part of the disc is on the left hand of an engine-driver, it indicates that the left-hand road is blocked; when on the

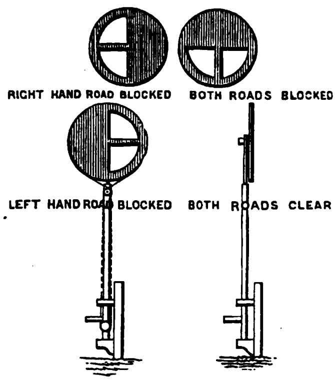


Fig. 84. London and South-Western Railway Signals.

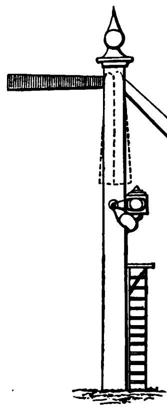


Fig. 85. Semaphore signal.

right hand, that the right-hand road is blocked; and when the solid part is upwards, it shows that both lines are blocked.

The signal known as the Semaphore signal (fig. 85), introduced on railways about 1841 by Mr. C. H. Gregory, has, however, been found so superior to all the other types, that it is rapidly superseding all the other signals, and before long it will probably be the only daylight fixed signal used in this country.

The semaphore signal, as applied to railway traffic, consists of a vertical post, which has one or more movable

boards, or arms, pivoted to it at their upper ends, and these arms are capable of being moved through a right angle. If the three signals of 'All right,' 'Caution,' and 'Danger' are in use the semaphore signal exhibits them in the following way; when the board is hanging vertically (as shown by dotted lines in fig. 85), and is concealed by the post, the signal denotes 'All right!' when it is inclined at an angle of 45 degrees (as shown on the right hand side of the fig.), it denotes 'Caution!' and when it is raised to the horizontal position (as shown on the left hand side of the fig.), it means 'Stop!' At night a lamp is used, with coloured glasses worked by the same rod which works the semaphore arms; when three signals are in use the white light means 'All right!' the green light 'Caution!' and the red light 'Stop!'

The semaphore signal post often has arms on both sides of it, and occasionally, at stations or junctions, two or more tiers of arms, one above another; but in all cases the arms on one side refer to trains proceeding in one direction, and the arms on the other side to trains proceeding in the other direction. The driver of any train approaching the signal post has to consider only the arms on the left hand, or 'near' side, of the post. The arms are painted red on the side which faces the approaching train to which they refer. The other side of the arm is generally painted white, so as to be comparatively invisible. Occasionally distinguishing symbols are placed on different arms, so as to assist in distinguishing the different signals. At complicated junctions or stations the signals are sometimes arranged on a narrow platform carried on the top of a post, and the main line signal is generally elevated above the other signals, as seen in fig. 86. In the arrangement shown the signals refer to trains proceeding in one direction only, and

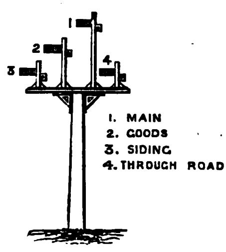


Fig. 86. Arrangement of Semaphore Signals.

there would, in such a case, be a similar post and platform carrying signals for trains proceeding in the other direction.

The caution signal above mentioned, is, as has been said, being gradually discarded, and only two signals used; that is to say, the arm at 45 degrees and the green light are now in many cases taken to mean 'All right!' and the horizontal position of the arm and the red light to mean 'Stop!' The block system having rendered a third or cautionary signal unnecessary, it is an advantage not to have to use a white light for signalling 'All right!' in or near towns, where such a light may be confused with ordinary white lights. In other positions the white light has the advantage of being much more visible than a green light, and this is of consequence when trains are travelling at high speeds. The vertical position of the semaphore arm, which was the original 'All right!' signal, can scarcely be considered a signal, but rather the absence of a signal. It is always desirable that an engine-driver should have a distinct affirmative intimation before he proceeds, and with the semaphore arm at an angle of 45 degrees, and with the use of the green light, this object is obtained. Where, then, only two signals are required, viz. 'All right!' and 'Danger!' the latter is always given by the horizontal position of the semaphore arm and by the red light, while the former is generally, and certainly best, given in daylight by the semaphore arm inclined at an angle of 45 degrees, and at night either by the green light or by the white light, according to the particular situation of the signals.

In all cases signals should be counterweighted, so that their tendency is to assume the position indicating 'Danger!' Thus, if a wire or rod breaks, the signal at once flies to 'Danger' and stops all traffic, and the worst that can happen is delay. If the signals were not counterweighted, the weight of the semaphore arm itself might make it assume the position of 'All right!' if the wire or rod were broken, and such a signal might produce a collision or some other disaster.

At each signalling station a semaphore arm is required for each line of way on which trains travel, and at junction signalling stations it is best that separate signal posts should be provided for the main lines and branch lines. Where sidings join a main line they should be treated as junctions of a branch railway, and signals should be used for all traffic entering or leaving the main line at such sidings.

The main signals of any signalling station are generally placed over or very near to the signal box or cabin in which the signalman is stationed, but there are auxiliary signals worked from the cabin in either direction. In consequence of the speed at which trains travel, it is necessary to let engine-drivers know how the 'home' signals (as the signals on the signal boxes are generally called) stand before they sight them, so that they may have time to slacken speed, and, if necessary, come to a standstill at the 'home' signals. This duty is performed by what are termed 'Distant' and 'Auxiliary' signals, which are placed from a quarter to a half mile away from the 'home' signals, and are worked by wires connected with the levers in the signal box.

The rules of most railway companies prescribe that an engine-driver, if he finds the distant signal at 'Danger,' shall bring his train so far under control that he can stop at the distant signal if necessary; but that he shall, if no obstruction is found at the distant signal, proceed slowly within the signal, so that the rear of his train may be protected by it, until he gets a signal from the 'home' signal box to proceed.

Distant signals should, when possible, be so placed that they can be seen from the 'home' signal box, in order that the signalman may see that the signal has obeyed the movement of the lever in the signal box by which he works it. This is necessary, as, when the wires are very long, the contraction and expansion or the stretching of the wires becomes of importance, and a signalman may think he has properly adjusted the distant signal when he has done no more than

taken up the slack of the wire. When the signal is in view of the signalman he can of course see by day in clear weather how it stands ; and, to give him the same information by night the distant signal lamps have small lenses at their back, facing towards the main signal box, called 'back lights,' and movable coloured glasses connected with the coloured glasses which, facing in the opposite direction, constitute the main night signals, are brought in front of the back light; the different colours exhibited at the back light thus show a signalman whether his distant signal stands at 'All right!' or 'Danger!' The colours generally adopted for the back lights of distant signals are white and purple, neither of which lights would be taken as a signal affecting an engine-driver approaching the back lights on the other line of rails.

In positions where the distant signal cannot be seen from the main signal box, mechanical or electrical 'Repeaters' are used for the purpose of showing the signalman how his distant signal stands. The mechanical repeater acts as follows—A wire is connected with the semaphore arm, so that the movement of the arm either moves another arm within sight of the signalman, or moves an indicator, such as a disc or small semaphore, in the signalman's cabin. Thus, when, by the movement of a lever in the signal cabin, the semaphore arm of the distant signal has been properly lowered or raised, the repeating wire, which is independent of the wire attached to the signal lever, is tightened or released, and, a corresponding movement of the indicator in the cabin, informs the signalman that the proper movement of the distant signal has taken place. The alteration in the length of the repeating wire from temperature or other causes is an objection to the mechanical repeater, and constant attention to the condition of the wire is required.

This objection does not attach to the electrical repeater (fig. 87), which is generally a miniature semaphore or disc placed in the signalman's cabin, and worked by an electro-magnet. The magnet is connected by a wire to the distant

signal, and works by contact being made or broken at the distant signal, so that the movement of the distant signal is repeated in miniature on the small signal in the signal box. Electricity has also been employed to show a signalman whether the lamp of his distant signal is or is not alight, which is a matter of great importance where the distant signal cannot be seen from the signal box. The temperature of the lamp maintains the contact of two wires connected with an electro-magnet; if the lamp goes out and the temperature falls, contact is broken, and notice is given to the signalman by a small alarm bell being rung and by the word 'In' shown on the miniature signal changing to the word 'Out.'

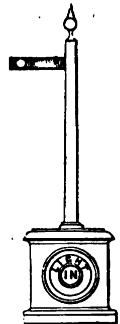


Fig. 87. Electric Repeater.

Daylight signals should in all cases be placed, if possible, so that they have a background of sky, or else it is difficult to see them. This necessity occasionally entails the elevation of the signal arm to a great height above the rails, with the accompanying disadvantage that the semaphore arm will be invisible at the rail level in foggy weather. In such cases a duplicate semaphore arm and lamp connected to and working with the upper arm should be placed on the same post, about 10 or 12 feet from the rails, so that the engine-driver may be able to see the signal during thick weather as he passes it. When a signal has of necessity a dark background, such as an abutment of a bridge or trees, or the slope of a railway cutting, it is frequently the practice to paint the abutment white, or to put up behind the signal a white board, against which the red arm of the semaphore can be clearly seen.

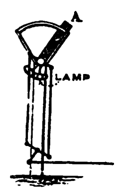


Fig. 88. Point Indicator.

Fig. 88 shows a small signal used to show an engine-driver which way the switches of sidings stand. The small board (A) is moved by the rod

which works the points to the right or to the left side of the quadrant, in accordance with the movement imparted to the switches. Fig. 89 shows a signal for sidings which is fixed near the ground, and is turned round so as to exhibit a signal, by means of a disc and coloured lights, to show whether an engine-driver may travel in or out of the siding. These two last signals are very useful in station yards and other similar situations in which it is undesirable to increase the number of high signals, which can then be kept for the service of the main roads.

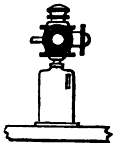


Fig. 89.
Ground Disc and lamp.

Special and audible signals are used in fogs to supplement the visible signals. The ordinary fog signal (fig. 90) is made of detonating composition, enclosed in a flattish metal capsule. The capsule is furnished with two thin metal clips, which can be bent round the rail so as to prevent the capsule from slipping off accidentally, and the pressure of a wheel causes the detonating composition to explode. In foggy weather a platelayer or some other person is stationed at the foot of the signal posts and at other convenient positions, and his duty is to place and keep one or two detonating signals on the rails whenever the semaphore arm is at 'Danger!' removing the detonators when the arm is at 'All right!' or 'Caution!' The detonating signals are used largely under other circumstances as (for example) in the case of a train breaking down, or during repairs to the permanent way. All guards and engine-drivers are supplied with detonating signals for use in emergencies, and they are a most valuable addition to visible signals; for a man can shut his eyes, but he cannot shut his ears. The only danger connected with detonating or other audible signals lies in the possible failure of the detonating powder or other means employed for making a noise. With proper care, however, the risk of failure is small, and in all cases detonating signals should be used in duplicate.

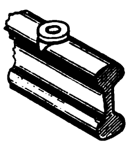


Fig. 90.
Fog Signal.

Means are sometimes adopted, although very rarely, of placing detonating signals on the rails by a lever connected to the semaphore arm, so that when the semaphore arm is put at 'Danger' the lever may place a detonator on the rails, and when the semaphore arm is put to 'Caution' the detonator may be withdrawn.

Other means for giving audible signals have been proposed, and may be said to be on their trial. The best known are those which act on the whistle of the locomotive or on gongs on the locomotive, or in the guard's van. The method of their application is as follows (see fig. 91):—At the place at

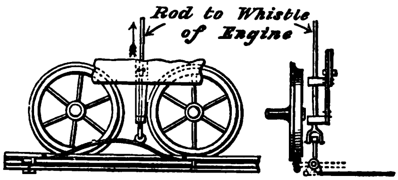


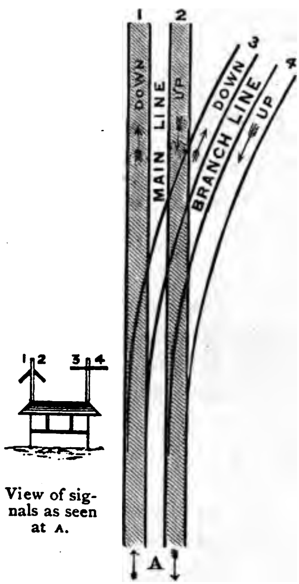
Fig. 91. Fixed Audible Signal.

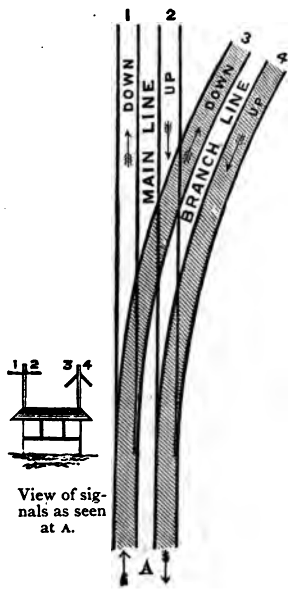
which it is desired to give an audible signal to those in charge of the train, a rigid or elastic inclined plane is placed so that a pendent rod connected with the steam whistle or gong may be raised by it as the engine or van passes. The raising of the pendent rod opens the whistle or causes a weighted hammer to strike a gong, and thus attracts the attention of the engine-driver or guard. The inclined plane is made movable, so that when the semaphore arm is at 'All right' the inclined plane is altogether removed, but when the semaphore is at 'Danger' the inclined plane is placed so as to engage with the end of the pendent rod. The same object has been attained by means of electricity, the making and breaking of contact being caused by much the same means as above described. Of course any such system requires that every engine not only of the company on whose line the audible signals are used, but also those of all companies working over the railway,

should be furnished with the proper rods and levers to open the whistle or to strike the gong. It is quite possible that a system of this sort may be found valuable as an adjunct to visible signals, but it is not probable that it will replace them, as they are simpler, less liable to derangement, and, except in thick weather, more efficient than audible signals.

Interlocking Signals.

The principle of the interlocking of points and signals has now to be considered. In passing from one line





Diagrams of junctions.

Fig. 92. Points and signals right for up and down main lines.

Fig. 93. Points and signals right for up and down branch lines.

of rails to another trains 'foul' (as it is technically called) all the lines which they cross, including the line from

which they start, and the line on which they eventually arrive. During this time all other traffic on these lines must be stopped. In figs. 92 and 93, two diagram plans are given of an ordinary junction with a double main line of rails, and a double branch line. In the first plan the points are set open for both the main lines, and in the second plan for both the branch lines, the paths along which trains would travel, being in each case shaded. It is obvious that so long as a train is passing from the main down line to the branch down line, all traffic, excepting upon the branch up line, which is parallel to the branch down line, must be stopped, because any train travelling on the main up line, might cut the branch down train in two as it crossed over the main up line. It would, however, be quite safe for a main down train and an up branch train to pass at one time, and the arrangement of the signals and points to effect this is shown in the diagram (fig. 94). The three diagrams (figs. 92, 93, 94) show the only safe combinations of two trains passing the signals at one time.

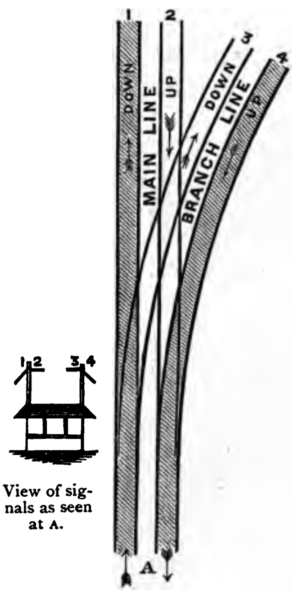


Fig. 94. Diagram of junction. Points and signals right for main down and branch up lines.

At such a junction there would be two semaphore signal posts, with two arms on each, the two arms on the left-hand post in the diagram would refer to the two main lines, and the two on the right-hand post (being on the side on which the branch line

diverges from the main line) would refer to the two branch lines. Sometimes independent signal posts are placed on each side of the line, instead of their being fixed over the signal box. In addition to these signals there would be the 'distant' signals placed about half a mile away from the main signals, and worked by wires from the signal box. These 'distant' signals should be 4 in number, corresponding with the signals on the main posts.

Assuming that at an ordinary junction of two branch lines joining two main lines there are 2 point levers and 4 signal levers (neglecting for the moment the distant signal levers), there would be of the above 6 levers 64 possible combinations. The signals might be arranged in any of the 16 ways shown in fig. 95, and the points might occupy any

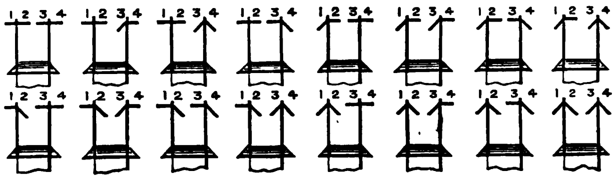


Fig. 95.

of 4 positions irrespective of the position of the signals. Of the 64 combinations thus possible only 13 are safe, and the rest would be such as might lure an engine-driver into danger.

Formerly a signalman at such a junction could, as was his duty, adjust the points first, and then lower the signal to allow an engine-driver to pass; but he might lower the signals without adjusting the points, and there was no mechanical contrivance to insure the signalman's giving all signals in accordance with the position of the points. It was consequently quite possible in that state of things, and it occasionally happened, that the signalman would give a signal for the branch down train and the main up train to come up at the same time, and so cause a collision.

About the year 1846 it had begun to be the custom to concentrate as many signal and point levers together as could be conveniently worked by one man; and for this purpose the points and signals were connected to their levers, by rods and wires of such a length as might be required. The concentration, however, introduced the danger of the signalman pulling a wrong lever by mistake which might easily happen if he had 10 or 20 levers before him. To counteract this danger, Mr. Stevens in 1847 invented a plan by which the signalman worked the points with an ordinary point lever, and the signals by means of a stirrup placed immediately adjoining the point lever to which the signals applied. Thus, when the signalman moved the points with his hand he moved the signal with his foot, and this arrangement to a certain extent counteracted the dangers of concentration. There was, however, no mechanical obstacle to the signalman moving a stirrup before he moved a point, nor was there any mechanical connection between different levers or different stirrups.

In certain cases it is desirable, in order to avoid multiplying the number of signals, that two signalmen should control one signal, so that the consent of both men should be necessary to allow a train to pass the signal. This is effected in a simple way by having slots in the rod which works the signal (shown in fig. 96, see next page), in each of which slots a pivoted lever can be moved up and down, and one lever is worked by one signalman and the other lever by the other signalman. Supposing that each lever is at the lower end of its slot, and that either lever in that position retains the semaphore arm at 'Danger,' then if one signalman moves his lever, the other lever will still uphold the semaphore arm, and consequently the first signalman's lever will be inoperative so far as giving a signal is concerned. When, however, the second signalman moves his lever the remaining obstacle to the movement of the semaphore arm is withdrawn, and the signal falls by gravity, in agreement with the concordant intentions of the two men.

This principle of slotting signal or point rods is capable of almost unlimited extension, and any number of slots, in each of which a pointed lever or a pin may work, may be placed in any suitable position in the system of rods. As the different pins can be worked by different handles signals may thus be so arranged that the consentaneous action of certain signalmen will be required, or one man may have to move any number of handles specified, before a signal can be given for a train to pass.

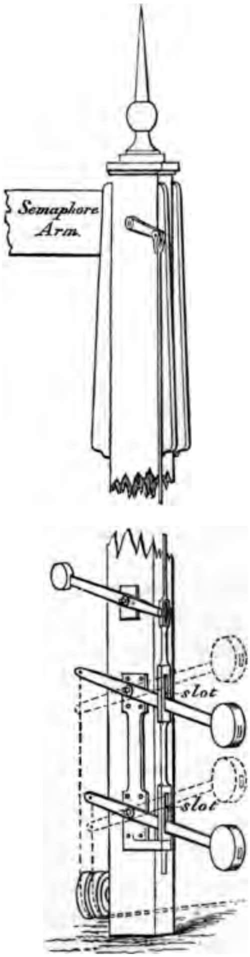


Fig. 96.

The system of controlling the motion of rods by pins working in slots was the germ of the system introduced by Mr. Saxby in 1856 in his invention of combined interlocking signals, by which the points and signals of any junction, however complicated, were connected together in such a way that it was mechanically impossible that the position of the points should be at any time contradictory to the position of the signals, or that incompatible signals should be given.

When this principle is extended from an ordinary junction (such as is shown on the dia- [redacted]. 92, 93, and 94) to a complicated station yard

or to a junction with many intersecting lines, the problem becomes more intricate, but the system itself is capable of indefinite extension, to suit any system of railway working. When there is a complication of lines, the value of the invention is the greater because of the greater liability in such a position to mistakes of various kinds. At Cannon Street Station, for example, where there are nearly 70 point and signal levers concentrated in one signal house, the number of combinations which would be possible if all the signal and point levers were not interlocked can be expressed only by millions. Of these only 808 combinations are safe, and by the interlocking apparatus these 808 combinations are rendered possible, and all the others impossible.

If a man were to go blindfold into a signal box with an interlocking apparatus, he might, so far as accordance between points and signals is concerned, be allowed with safety to pull over any lever at random. He might doubtless delay the traffic, because he might not know which signal to lower for a particular train, but he could not lower such a signal or produce such a combination of position of points and signals, as would, if the signals were obeyed, produce a collision. The results of the interlocking principle may be illustrated by the example of a piano or organ, constructed in such a way that no notes could be played on it which are not in harmony with each other.

Since 1856, up to the present time, various improvements have taken place in this system, which now is known as the Interlocking System. Various inventors have introduced different modes of carrying out the same fundamental principle, viz. that in no case should it be possible, through inadvertence, or carelessness, or misconduct, for a signalman to give conflicting or dangerous signals. The first invention —though it went to the root of the interlocking principle, and indeed effected the immense improvement that conflicting signals could not be given, and that the signals could never be contradictory to the position of the points—

was much improved by Mr. Chambers and Mr. Saxby in 1860. The apparatus, as thus improved in 1860, will serve to exemplify the principles of interlocking, and will first be described.

All the levers required to work the points and signals of any particular junction or station are concentrated side by side in a cast-iron frame. The points and the signals are connected with the levers by long rods or wires, and cranks are used where the direction of the rods or wires is changed.

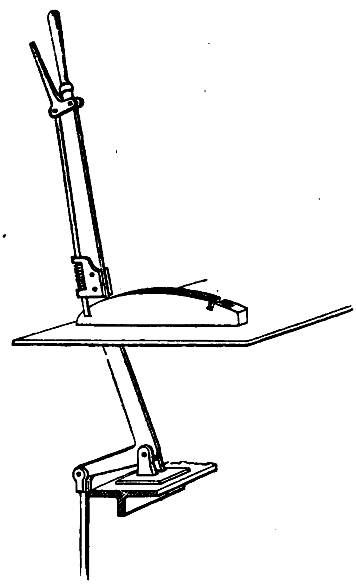


Fig. 97. Point or signal lever in frame.

A point or signal lever (fig. 97) is generally a bent lever and is pivoted on the bottom plate of the frame. To the short end of the lever, a rod or wire is attached, which is connected with the point or the signal. As the lever is worked backwards and forwards, the points are moved from one position to another; or, in the case of a signal lever, the signal is raised or lowered. Above the top plate of the frame there are a pair of segmental guiding plates, between which the lever slides. This pair of segmental plates is technically called the quadrant, and in it are cut notches at a proper distance from each other, corresponding with the distance through which the lever should be moved, for the purpose of working the points

or signals properly. Into these notches fits a sliding bolt, similar to the catch which may be seen on the reversing lever of a locomotive engine, which moves up and down in a vertical direction against the front of the lever, according as the handle at its upper extremity is grasped or released by the hand of the signalman. When the sliding bolt is in either of the notches, the movement of the lever is complete, and so long as the sliding bolt is in the notch the lever cannot be moved. Thus, before any motion can be given to a lever, the handle of the sliding bolt—or, as it is more generally called, the spring catch rod—must be grasped by the signalman's hand so as to lift the lower end of it out of the notch in the quadrant; and when the movement of the lever is complete, the spring catch rod drops, or rather is forced by the spring, into the other notch at the other end of the quadrant.

The sliding bolt, or spring catch rod, has been described in detail because, as will hereafter be seen, it fulfils very important functions in interlocking apparatus, and especially in the most recent improvements.

In the interlocking apparatus now referred to, the point or signal levers, 1, 2, 3 (fig. 98, p. 116), as they are moved backwards or forwards, impart a horizontal movement at right angles to the motion of the lever, to one or more long bars, X, Y, Z (fig. 98), which extend from end to end of the apparatus. These bars are called locking bars and move what are called locks. The locks, C, D, E, F, &c. (fig. 98), are bars or plates of iron, which have inclined sides, and some of them have notches and projections. One end of each lock is carried by one of the locking bars, and the other end is pivoted at the side of the apparatus opposite to the locking bar on a long fixed pin extending from the top plate to the bottom plate of the frame. When the locking bar is moved by the lever, the notches or projections of the locks are brought before, behind, or are moved away from

other levers, and so hold fast or release those other levers as may be required.

The modes by which motion is given by the lever to the locking bars vary in different apparatus. The functions of the locking bar in the apparatus now referred to, and shown generally in fig. 98, will be better understood from the plans in figs. 101, 102, 103. In the arrangement under consideration

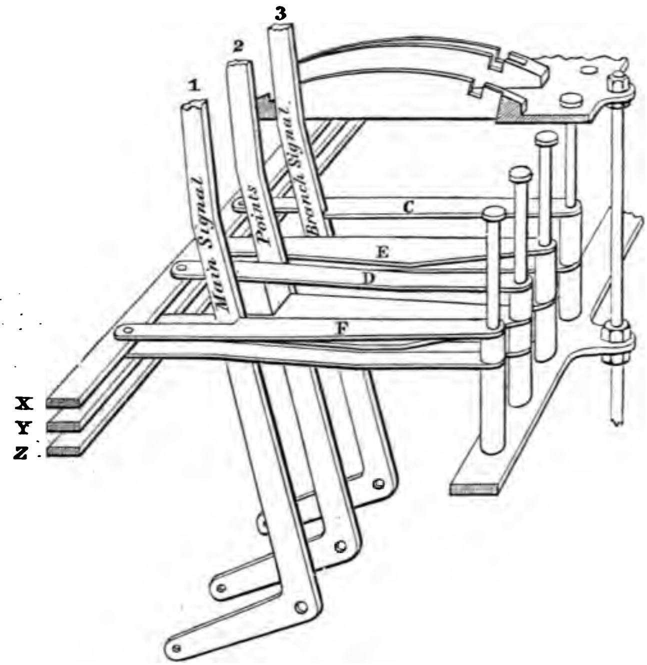


Fig. 98. Combination of point and signal levers.

the lever pushes against an inclined or a wedge-shaped plate, and so makes the locking bar slide at right angles to the direction of the path of the lever; in other apparatus the locking bar is moved by rocking shafts, and many other

means might be and have been devised for imparting motion to the locking bar through the agency of the point or signal lever.

The sketch (fig. 99) shows in plan the top plate of an apparatus with three levers 1, 2, 3, drawn in section. This is the smallest number of levers which will effectually exhibit the action of the interlocking gear, but the principle embodied in the interlocking of three levers can be indefinitely extended to any number of levers by multiplying the parts of the apparatus. In the three-lever apparatus (fig. 90) it will be assumed that the middle lever (2) works the points, and the other two levers (1 and 3) work signals; one signal lever (1) working the signal for the main line, and the other signal lever (3) the signal for a branch line diverging from the main line. The plan of a junction worked by such

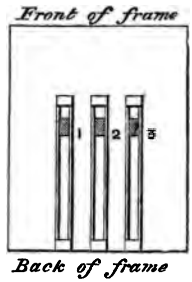


Fig. 99.
Plan of top plate of a three-lever apparatus.

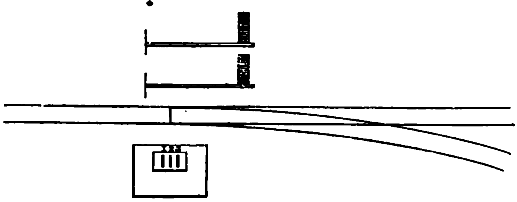


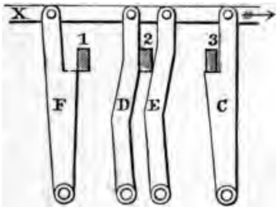
Fig. 100. Plan of a single junction worked by a three-lever apparatus.

an apparatus would be as shown in fig. 100. When the point lever stands to the front of the frame, the points will be right for the main line. Also when the two signal levers are standing to the front, both the signals will be at 'Danger!' and when they are at the back of the frame, the signals will be at 'All right!'

In an apparatus of three levers there would be three horizontal locking bars one above the other, and each bar would carry its own locks; and three plans (figs. 101, 102, and 103), are therefore given, which are taken at different levels, and

show each of the three horizontal bars with its accompanying locks. When both signals are at 'Danger!' and when consequently no trains can pass along either line, the points should be capable of being moved either way. This is required so as to allow of shunting being possible under the protection of the signals, and for other reasons. By inspection of the plans (figs. 101, 102, and 103), it will be seen that when the signal levers are in the positions shown thereon, and when consequently both the signals are at 'Danger,' no obstacle in any of the plans exists to the lever No. 2 being moved backwards and forwards. In fig. 101 it will be seen that lever No. 3, which works the branch line signal, cannot be moved, because there is a projection of a bar, or lock, C, interposed behind that lever. When the points stand right for the main line, the lever No. 2 being to the front of the frame, the main line signal ought to be capable of being lowered, and on inspection of the three plans it will be seen that no obstacle exists to lever No. 1, which is the main line signal lever, being moved to the back of the frame, and the 'All right' signal given; but it will be seen that in moving this lever backwards it will slide against an inclined edge of a lock, A, shown in fig. 102, one end of which is pivoted to the back of the

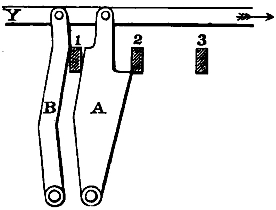
Front of frame.



Back of frame.

Fig. 101. Interlocking gear.

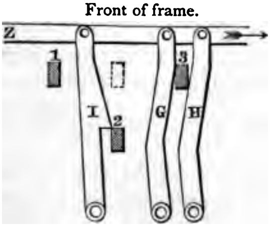
Front of frame.



Back of frame.

Fig. 102. Interlocking gear.

Front of frame.



Back of frame.

Fig. 103. Interlocking gear.

frame, while the other end is attached to the locking bar Y at the front of the frame, and will thus push the locking bar Y from left to right. Opposite to lever No. 2 (the point lever) the bar A has a recess cut in it, forming a shoulder; and by the movement of lever No. 1, causing the locking bar Y to slide, this shoulder will be moved behind the point lever, and will prevent any movement of the point lever. Thus the combination is effected that, the signal cannot be given for a train to pass along the main line, unless the point lever is in the proper position for the main line; and that giving the signal renders the point lever incapable of movement. If the main line signal be now put back again to 'Danger!' by moving the lever No. 1 to the front of the frame, it will be seen that the movement of lever No. 1 against the inclined edge of the bar B will move the locking bar Y from right to left, and put things again in the original position, with all the levers standing to the front of the frame. Supposing now that it is necessary that a train should pass from the main to the branch line, and that consequently the branch signal must be lowered to 'All right!' It is seen (fig. 101) that when all the levers are to the front of the frame the branch signal lever No. 3 is prevented from moving by the projection of the lock C. In order to withdraw this projection the locking bar X has to be moved sideways from left to right. In order to set the points right for the branch line the point lever No. 2 has to be moved from the front to the back of the frame. In doing this the lever No. 2 will press against the inclined face of a bar E (shown in fig. 101), and in doing so will cause the locking bar X to move from left to right; when the movement of lever No. 2 is completed, the whole of the projection of the lock C will be removed from the path of lever No. 3, which can then be moved to the back of the frame, and so the branch signal can be given. The same locking bar X has attached to it, opposite to lever No. 1, a bar F with a shoulder, which, by the same motion as unlocks No. 3 lever, will lock No. 1 lever. Thus this combination is ef-

fected, that the act of setting the points right for the branch line will lock the main line signal, and unlock the branch line signal. Lastly, it will be seen by fig. 103 that if the branch line signal lever No. 3 be brought to the back of the frame, this lever will press against the inclined edge of the bar H, and so will move the locking bar Z from left to right, and bring a projection on the bar I in front of the lever No. 2 when this lever is in its back position. Thus the movement of the lever No. 3 to the back of the frame giving the 'All right!' signal for the branch line, locks the point lever No. 2, which will be then in its back position in the frame (the points having been set for the branch line), in the same way as that described above, the movement of the signal lever No. 1 to the back of the frame giving the 'All right!' signal for the main line, locked the point lever in its forward position with the points standing right for the main line.

This form of apparatus was no doubt a great improvement on all that had gone before, and so long as the moving parts were not much worn, it worked well. It was, however, found that from wear and tear—and an interlocking apparatus at a busy station is never idle—the inclined sides of the bars, or the sides of the locks, became worn, so that the locks were not always accurately moved into their true positions, and consequently that the locks did not always hold the levers fast, as they were intended to do. Moreover—and this was a greater defect—from the locks being placed opposite the levers at but a small distance above their fulcrum, the strain produced against the lock, if the signalman tried to move a locked lever, was very great, and threw too great a stress on the interlocking gear.

This difficulty is got over in the more modern apparatus by further utilising the spring catch-rod, alluded to above, which fitting into notches in the quadrant, determines the beginning and the end of each stroke of the lever. If the *movement* of a lever by working a locking bar be made to hold *fast or release the spring* catch-rods of other levers, instead

of the levers themselves, the straining of the apparatus which had been found so detrimental is avoided; because as it is impossible to move a lever until the spring catch has been raised out of the quadrant, the signalman, if the spring catch-rod be held fast, cannot even commence the movement of a lever which ought not to be moved. Thus the strains due to the long leverage of the point and signal levers are not brought against the locks, and the whole of the interlocking gear can be made much lighter, and can be worked with less friction.

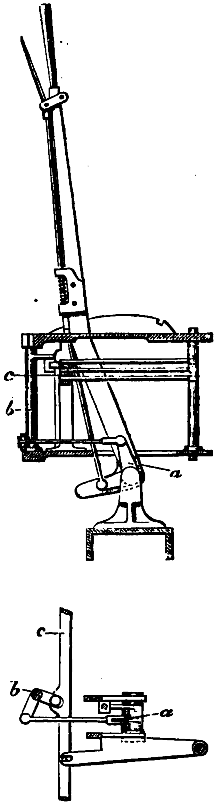


Fig. 104.

A further improvement is that the upward and downward motion of the spring catch-rod is made the means of actuating the locking bar, irrespective of the movement of the main levers. One of the early modes carrying out this idea is shown in fig. 104. As the spring catch-rod of any lever is grasped by the signalman's hand, and is raised out of the notch in the quadrant, or as it is released and is forced downwards by the spring into the notch, a movement is given to the locking bar, *c*, by means of the bell crank, *a*, turning the spindle, *b*; and all the necessary locking and unlocking is performed independently of the movement of the lever itself. In this way the spring catch-rod becomes not only the recipient of the locking, but also the actuator of the locking, and as a consequence it may be said that the intention of the signalman to move any

lever, expressed by his grasping the lever and so raising the spring catch-rod, independently of his putting his intention in force, actuates all the necessary locking.

The locking bar in some form or other is common to all the systems of interlocking, and the difference between the old and new apparatus is in the mode in which motion is imparted to the locking bar, and the mode in which it controls the levers.

Fig. 105 shows a locking apparatus of the most modern description actuated exclusively by the spring catch-rod. In this arrangement the whole of the locking gear is above the floor and in sight of the signalman, and easily accessible for oiling and repair. The movement of the spring catch-rod works the locking, and consequently the locks are put on or taken off at each end of the stroke of the lever when the spring catch is raised out of, or allowed to fall into, the notch in the quadrant. The principal novelty in the mechanism is the rocker, D, which is a 'slot link' or segmental plate with a curved slot in it. The lower end of the spring catch-rod carries a stud, upon which is a small block, B, travelling in the curved slot in the rocker. When the main lever is in its normal position, and to the front of the frame, and the spring catch-rod is down, the left-hand end of the rocker is depressed and the right-hand end raised, as shown in fig. 105 by the dotted lines of the more distant rocker. Upon raising the spring catch-rod out of the notch in the quadrant, the rocker is moved into a position as shown in the nearer rocker in the drawing, in which position the curve of the slot corresponds to the radial course of the block when the main lever is being moved. The nearer lever, C, is shown out of its normal position, the spring catch-rod being raised, and the rocker being therefore in the second position. As the spring catch can fall only into the notches at each end of the quadrant it follows that the rocker is not moved during the stroke of the lever, because the stud when the lever is moved only travels in a slot which is

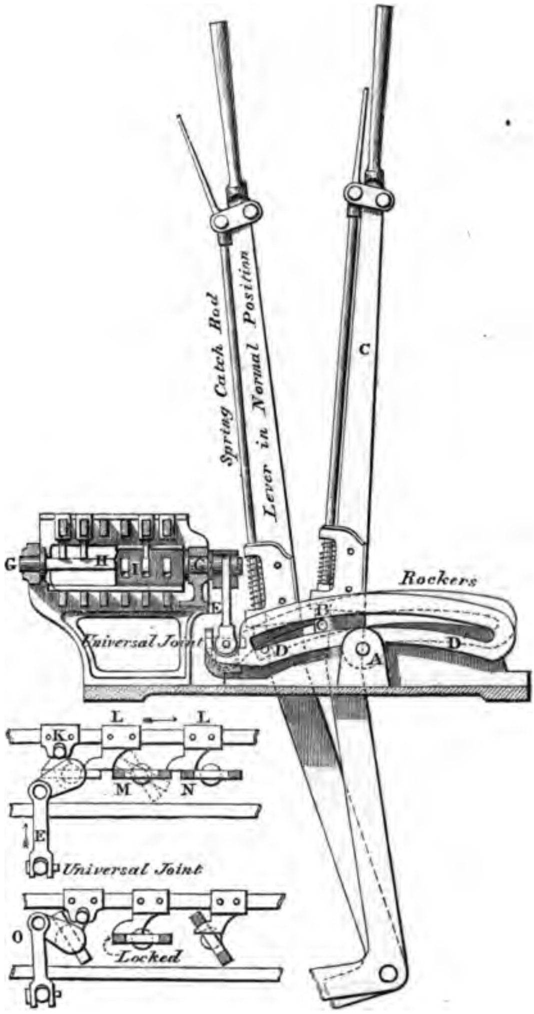


Fig. 105. Modern Interlocking Apparatus actuated by spring catch-rod.

radial to the centre on which the lever itself moves. When, however, the main lever is over, and the spring catch-rod is let down into the notch at the back of the frame, the rocker is moved to a third position with the left-hand end high and the right-hand end low. At the left-hand end of the rocker is a jaw which carries a universal jointed vertical link E. This link gives motion to a small crank at the end of a spindle, the bearings of which are shown at G G. The intermediate portion of these spindles is flat, and when they stand in their normal position the locking bars are free to travel over them, as shown at H; but when they are canted up (as in the case of the spindle shown broken off at I) they offer an obstruction to the movement of the locks attached to the locking bars. The action of the locking will be more readily understood by referring to the two front views given in the left-hand corner of fig. 105. In the upper view it is assumed that the rocker connected with the vertical link E is in the first position, the link E is in its normal position, the crank is inclined downwards, and the flat part of the spindle is horizontal. The two other spindles, M and N, are those worked by the rockers of the two adjoining levers, but their cranks are removed in order to show a section of the spindles. Each spindle that works a locking bar is provided with a short vertical crank, the stud of which works between two horns on the locking bar, as shown at K, so that when the spindle is moved a horizontal motion is given to the bar. The locks, L L, are fixed on the locking bar in such positions that some of the spindles are free to move, as at M, and some are locked, as at N. It will now be understood that whenever the spring catch of any lever is raised its rocker is lifted, and the corresponding spindle is turned; thus a very small amount of movement of the spring catch will cant the spindle up sufficiently to prevent the appropriate locks from being moved. The spindles being connected to the rockers may, like them, occupy three positions. These are shown at M: 1st, the normal, or horizontal position, is shown by full lines;

2nd, an intermediate position, when the main lever is being moved, as shown by dotted lines; and 3rd, the third position (also shown by dotted lines) is that which the spindle occupies when the main lever has been pulled over and the spring catch released. The right-hand end of the rocker is then depressed, and the other end with its link raised, as shown at O, in the lower front view. The third position of the rocker plays a very important part in the locking, because until that position is fully attained some of the locks are not released. If, for instance, a spindle stands locked, as shown at N, it is not released until by the movement of another spindle into the third position, shown at O, the lock on the locking bar has travelled sufficiently in the direction of the arrow to stand over a hole in the flat spindle N in which case the spindle can be turned up in front of the projecting beak of the lock, as shown in the case of the right-hand spindle in the lower view. The spindle N now prevents the return movement of the lock, and consequently the point lever which, by means of the link, O, works the left-hand spindle, cannot be moved until the flat spindle, N, has been replaced in its first or horizontal position corresponding to the lowering of the spring catch-rod of its lever into the forward notch of the quadrant.

The machine above described indicates one of the methods of carrying out the principles aimed at in the best interlocking apparatus, which are that a signalman should not be able even to commence to make any movement of either points or signals until he has efficiently locked in their proper positions all points and signals that have any relation to the movement which he intends to make; and that until he has thoroughly completed the intended movement, and has ceased to meddle with the part of the apparatus which actually sets the points or signals in motion, all points or signals affecting the operation which he is performing must be securely locked.

The importance of this improvement may be best appre-

ciated by considering the class of miscarriage of interlocking which might take place in the older locking apparatus, described above (see pp. 116 to 120, figs. 98 to 103) in which, the effect of great wear and tear would be that the locking might not act as soon as a lever began to be moved, and consequently that a partial movement of another lever, which ought to have been locked immediately the first lever was moved, would be possible; and further, that the locking set in motion by a lever might be released before the movement of the first or actuating lever had been completed. In the former case, supposing the actuating lever in question were a signal lever, a pair of points might be moved out of their exact position while the signal was down, during which time the points should have been locked; and in the second case, if the actuating lever in question were a point lever, the signal might be put to 'all right' before the adjustment of the appropriate points was accurately completed. Both these dangers, which were found serious in practice, are obviated by actuating the locking gear by the motion of the spring catch-rod, or by some analogous arrangement.

The interlocking principle can be applied to any system of levers, and any lever can be interlocked with any other lever irrespectively of the work which each particular lever has to perform. Thus signal levers can interlock with signal levers or point levers, and point levers can interlock with point levers as well as with signal levers. This latter arrangement is occasionally of much consequence, as it is often desirable that a series of points should not be allowed to be put into one position, and a particular path so 'made' for a train to pass in one direction unless another series of points has been previously put in another given position, and a second path 'made' in such a way that vehicles shunting along it, or trains which might overrun or disobey the signals, might be prevented from entering on or crossing the path of a train passing, in obedience to signals, along the first-mentioned path.

It is manifest that in most junctions or station yards there are certain lines of road which converge so that any two engines or trains travelling on them will meet, and at such places the interlocking of points with points mentioned in the previous paragraph, is often extremely useful. A simple example of the application of this precaution is seen in an ordinary junction, such as shown in figs. 92, 93, and 94, pp. 108, 109, in which the apparatus should be so arranged that in addition to the interlocking of the points with the signals, the points of the branch down line should be so interlocked with the points of the branch up line, that before the branch down points could be moved to set the line for a branch down train, the points of the up branch line must be first moved to set the line parallel to the branch down line, and so divert any vehicles shunting or travelling the wrong way on the up line from crossing the path of the branch down train.

The gates of level crossings (fig. 107) are often interlocked with the signals so that when the gates are shut across the railway all the signals must be at 'danger,' and the signals cannot be lowered to 'all right' till the gates are shut against the road traffic and opened for the railway traffic. One arrangement for carrying this into effect is as follows: The gates are connected to a lever similar to a point lever, which by a rack and pinion movement will open or shut all the gates simultaneously, and that lever is made to interlock with the signals. There are stops or blocks (fig. 106) to prevent the gates from being moved when in their proper position by anyone except the signalman; these stops are made to rise out of the ground and fall below the ground, by the movement of a second lever interlocked with the signals, and also interlocked with the lever, which works the gates, in such a way that the gate lever cannot be moved till the stop lever has been first moved. The stops are self-acting in one direction, being shelving on one side and perpendicular on the other side, so that the gates as they

swing encounter the shelving sides of the stops, which give way downwards, and allow the gates to pass over them,

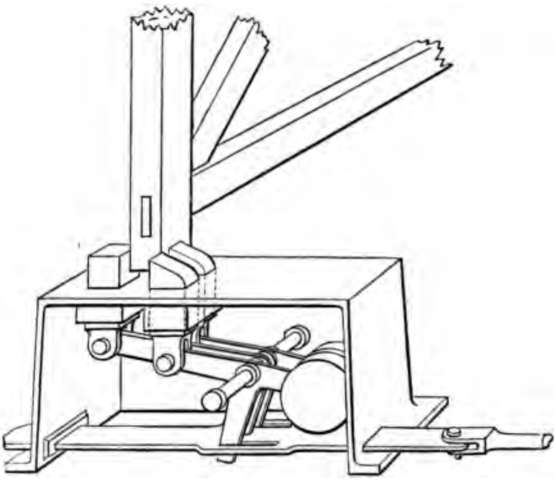


Fig. 106. Stops of level crossing gates.

but prevent the gates from being moved back again till the stops are lowered, by the stop lever. The stops are so con-

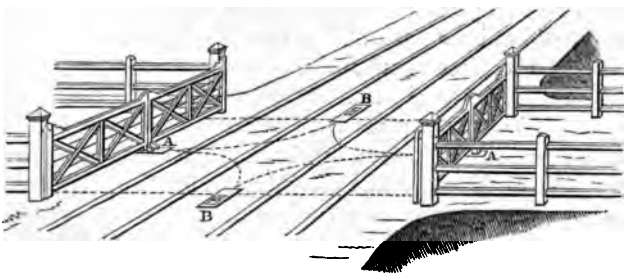


Fig. 107.

nected to the stop lever that as the stops A A (fig. 107) are
he stops B B are raised, and *vice versâ*. Supposing,

then, the gates are shut against the road traffic, as shown on fig. 107, and it is necessary to open them for the road traffic and to shut them against the railway traffic, the first thing to be done, so far as moving the gates is concerned, is to depress the stops A A by moving the stop lever; but the stop lever is so interlocked that it cannot be moved unless all the signals are at danger, and, further, the movement of the stop lever locks all the signals in the position of 'danger.' The signals being placed at 'danger,' the gate stops A A are lowered, and the stops B B are raised by one movement of the stop lever. Then by means of the gate lever, which also is interlocked with the signals, all four gates are moved into the position shown by the dotted lines, and pass over the shelving edges of the stops B B, which will hold them fast in their position across the line of railway. When the gates have to be put back again, that is, shut against the road traffic and opened for the railway traffic, the stops B B are depressed, and the stops A A are raised, but this does not unlock the signals, which are still kept at 'danger' by the gate lever interlocking with the signals. The gate lever is then moved back to its first position, and so moves the gates which pass over the shelving sides of the stops A A, into their proper position; and when the movement of the gate lever is complete, and not before it is complete, the 'all right' signals for trains to pass will be free.

Any arrangement for moving the gates by a lever should only be applied where the signalman can from his signal-box overlook and control the road traffic, or in cases where a porter can be stationed at the level crossing for the same purpose, as otherwise there is considerable risk that the gates in swinging to and fro may come in collision with persons or vehicles crossing the line.

The interlocking apparatus at present used more or less necessitates the concentration of a large number of point and signal levers in one frame, and under the hand of one man. The signalman is thus often of necessity placed a long way

from some of the points which he works, and the movement of the signalman's hand is conveyed to the points by long iron rods, and a series of bell cranks (fig. 108). The expansion

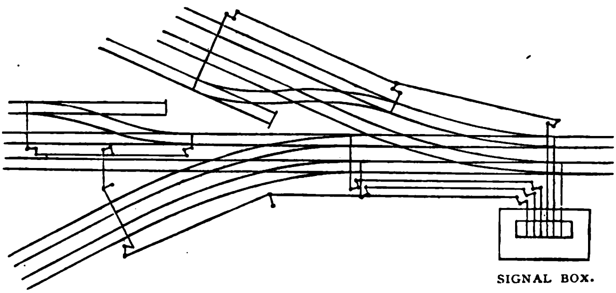


Fig. 108. Plan of point. Rods and cranks.

and contraction of these long rods, under the changes of temperature to which they are exposed, produce alterations in their lengths which have to be guarded against. Assuming a range of temperature of 60 degrees (no impossible contingency in this country) between a frosty night and a hot mid-day, an iron rod 300 ft. long, even if it be protected from the direct rays of the sun by wooden covers and by felt, would alter in length to the extent of about 1½ in. If the long rods alter in length the point lever may not accurately open and shut the points, and, as has been seen, in the chapter on points and crossings, a movement of about an inch, when the points are not tight to gauge, may turn a train into a wrong line. When interlocking apparatus was first introduced, the long rods were furnished with adjusting screws, and platelayers and signalmen had continually to inspect and to adjust the screws as the temperature altered. But it was soon seen that some self-acting adjustment was absolutely necessary, and the following simple plan has been adopted. The long rods are divided into approximately equal lengths, and their ends are connected to opposite ends of a short lever, which is pivoted at its centre

(fig. 109), and placed at right angles to the long rod. Thus any alteration of length in one piece of the long rod causing a movement of one end of the compensating lever

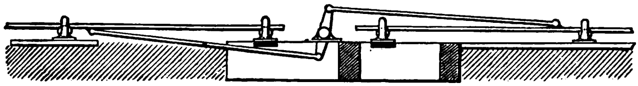


Fig. 109. Compensating lever.

in one direction is counterbalanced by the equal alteration in the length of the other part of the rod which is satisfied by the movement of the other end of the compensating lever in the opposite direction, and thus the motion of the point lever is transmitted unaltered in amount to the tongues of the points.

A truly mechanical plan, introduced by Mr. T. E. Harrison on the North Eastern Railway, for imparting motion to points is shown in fig. 110. A straight rod, attached to

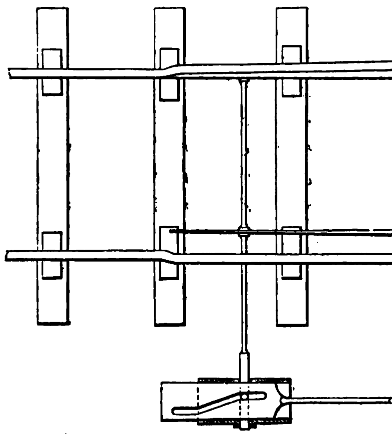


Fig. 110. North-Eastern Company's arrangement for point rods.

the tongues of the points at one end, carries at its other end an upright pin, which is placed in a slot of peculiar shape in

an iron plate. This iron plate is placed between guides, and is capable of movement to and fro in a direction at right angles to the direction of the movement of the points. The ends of the slot are straight and are in a direction parallel to the line of rails in which the points are fixed, and thus the first and last parts of a complete movement of the slotted plate do not affect the position of the points, but the necessary movement of the points is given by the curved part of the slot travelling past the pin. This arrangement prevents any little inaccuracy of fitting from permitting unwarranted movement of the points, as any slight slackness of the rods or locks only affects the motion of the straight part of the slot past the pin. The position of the pin in any part of the straight portion of the slot secures the points in a very effective way, as no movement can take place between the surfaces so placed at right angles one to the other. A further advantage is that the mechanism which determines the adjustment of the points is placed close to the points themselves, and consequently the alterations in the length of the long rods from changes of temperature are unimportant in their consequences.

An objection arises to the plan of working points from a signal box at a long distance from them, from the danger of a signalman carelessly or unwittingly moving the points while a train is going over them ; and there is also a danger of a rod breaking or becoming disconnected from the points without the knowledge of the signalman, in which case he might move the point lever, and so put in operation all the appropriate locking and unlocking in the apparatus, without any corresponding movement of the points themselves having taken place. Also, there is a danger with points worked from a distance of their not being completely shut, either from want of accuracy in adjustment of the working parts, or from a stone or some like impediment finding its way between the point and the stock rail. Such dangers were not chargeable against the old system, when pointsmen

stood close to their points and had their work well in view continually, but require to be carefully guarded against now that the points are worked from a distance.

If, as has been explained above (p. 87), facing points are left half open, or if, while the train is passing over them, the points are moved, part of the train will go one way and part the other, the train will probably leave the line and be wrecked. The interlocking gear prevents the signalman from moving the points while the 'all right' signal is exhibited, but it has been found more than once that a signalman has altered his signal to 'danger' while a train was passing the points, thus unlocking the points, and has immediately afterwards moved the point lever and produced a disaster by 'splitting' the train, i.e. sending part of the train on one line and part on another. This danger is particularly to be provided against with points placed a long way from the signal box.

The switch locking bar (fig. 111) was designed to meet this danger of facing points being moved during the passing

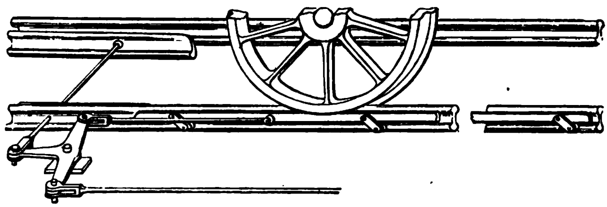


Fig. 111. Switch locking bar.

of a train. It consists of the following simple contrivance: A bar, at least as long as the greatest distance between any two pairs of wheels of any vehicle in use on the railway, is placed at the side of one of the rails immediately in front of the facing points, and is connected with the rod by which the points are worked. The bar is hinged on short links, so that it cannot be moved lengthways without at the same time rising. The top of the bar is level, or nearly level, *with the* top of the rails, when it is at either end of

its stroke, but when it is in mid position the top of the bar is some inches above the top of the rails, and this cannot take place if a wheel be over the bar. As the bar is longer than the greatest distance between any two pairs of wheels, it follows that from the time at which the first pair of wheels of a train comes over the bar to the time at which the last pair of wheels leaves the bar, the bar cannot be moved, and thus, as the bar is rigidly connected with the point rod, it is impossible for a signalman to impart any movement to the points during the passage of a train over the bar.

When first introduced the bar was connected directly with the lever which worked the points, so that, as the points were moved backwards or forwards, the bar was also moved at the same time on its hinges. But instead of connecting the switch locking bar directly with the points, so that one must be moved without the other, it has been found to be more desirable to work the switch locking bar by another lever in connection with an additional safety appliance called a 'switch bolt.'

The purpose of the switch bolt (fig. 112) is to ensure that facing points are in their proper position after they have been moved by the point lever, and before the signal can be given for a train to pass over them; also to securely and firmly lock the points in their proper position, when they have been adjusted by the point lever, so guarding against the points being disturbed by the vibration of a passing train. A transverse connecting bar, with two holes in it, is fixed at right angles to, and between the points, and a long bolt, made slightly taper, is fixed on the sleepers, between the rails, so that the bolt is shot parallel to the line of railway, through the holes in the connecting bar. When either of the holes in the connecting bar is opposite to the bolt, the bolt can be shot, and the taper on it tightens up the points, but in any intermediate position of the points *the bolt* cannot be shot, because there would be no hole *opposite to it.* Thus, if the points are not put thoroughly

home by the action of the point lever, the lever working the switch bolt cannot be moved; and, as the latter lever interlocks with the signal levers, no train can be signalled to approach until the points are accurately adjusted, and locked

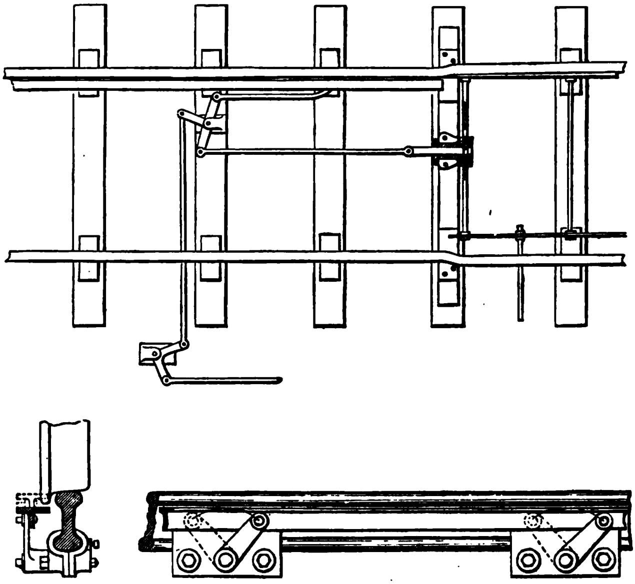


Fig. 112. Switch bolt and switch locking bar.

in their proper position. At the same time the switch locking bar, which is connected to the lever working the switch bolt, prevents the signalman from altering the position of the bolt while a train is passing over the bar.

Thus, when the switch bolt and the switch locking bar are in use, a signalman has, in order to adjust a pair of points for a train to pass over them, first to put the points in their proper position, and then to shoot the locking bolt. When these two operations are complete—and not before—he can give the signal to allow an approaching train to pass over the points. The switch locking bar at the same

time prevents the bolt from being withdrawn until the whole train has passed over the bar.

It is of importance that the locking bar should in all cases be so fixed that its end nearly touches the end of the points, and but little space is left between the bar and the points, in order that no appreciable interval of time may elapse between the passage of the last pair of wheels of a train off the locking bar, and on to the points.

A Double acting switch bolt (fig. 113) has been introduced, as an improvement on the simple locking bolt above

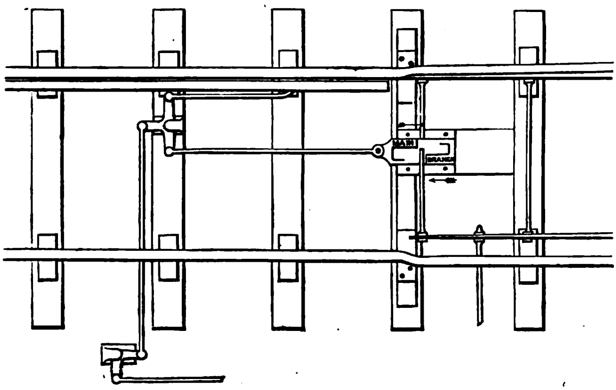


Fig. 113. Double acting switch bolt.

described. The object of the double bolt is, that in case the rod connecting the points with the apparatus should be broken between the signal box and the points, the signalman may have warning, and may be disabled from giving a signal which might be contradictory to the position of the points. In most instances all the inter-locking is performed in the signal box itself, and the locks are there applied to the point and signal levers. Thus, if the rod connecting the lever with the points be broken, the lever may be placed in its proper position, and may thus unlock a signal, though the

points may remain unmoved and be standing in the opposite direction.

The double acting bolt provides against this danger in the following way. There is only one hole, in the connecting bar between the tongues of the points, and the bolt is so placed that it is pushed at one time and pulled at another time into the hole from a central position, in which it is inoperative in locking, and in each of its extreme positions the bolt locks the points in their appropriate positions. Unless the hole in the connecting bar is opposite the bolt, the bolt cannot be shot, either by pulling or pushing the lever in the signal box. Assuming, then, that the bolt lever is always pulled in order to lock the points right for the branch line, and that the signalman finds that he cannot pull over the lever, he knows at once that the points are not standing right for the branch line, and that the lever which moves those points has not done its work; moreover, as the bolt lever is interlocked with the signal for the branch line, the signal for a train to pass on to the branch line cannot be given, because the bolt lever cannot be put in its proper position to unlock the signal lever. Thus any inconsistency between points and signals is rendered impossible even though the rod which works the points be broken.

There are many other contrivances and arrangements of mechanism for producing much the same results as those described in this chapter, but it is only possible, within the limits of this work to describe those mostly in use, and to refer to the characteristics of the more complete apparatus and to the principles observed in their construction. The signalling apparatus which have been of late adopted on our railways have attained a considerable degree of efficiency in dealing with a most complicated problem, and no doubt tend to greatly reduce the results of human fallibility.

CHAPTER V.

THE BLOCK SYSTEM.

IN Chapter IV. railway signalling has been considered as it is carried out between the signalman and the engine-driver. The subject of this chapter is the signalling which takes place between one signalman and another through the agency of the electric telegraph.

Before proceeding to the consideration of the block system, it is necessary to refer to a peculiar system of working traffic called the 'train staff,' or 'train staff and ticket,' system, used for working single lines of railways, and which are carried out as follows:—The railway is divided into districts A to B, B to C, C to D, and so on, and a staff like a policeman's truncheon is set apart as belonging to each district. To avoid confusion, the staffs are usually dissimilarly shaped, or made of dissimilar materials and the staff of one district must on no account be taken off that district. Under the 'train staff' system no engine-driver may start from any station forming the terminus of a district without having actually in his possession the staff belonging to that district, and as the staff cannot be in two places at once, it is impossible that a collision can take place between two engines.

Supposing that a train is travelling from A to D, the driver of the train will receive the proper staff at A, give *it up to* the station-master at B, receive another staff at *B, give that up at* C, receive another staff at C, and give

that up at D. As soon as the station-master at B, C, or D, receives the staff from the engine-driver he may allow a train to go in the opposite direction by giving the staff to the driver of the train wishing to go in that direction. The arrangement if rigidly adhered to manifestly ensures absolute safety from collision, but it is inconvenient and restrictive of traffic, because in order to return the staff to A to allow a second train to go from A to B there must be a return train ready to start from B to A, or the staff must wait at B until this is the case. On many lines the tide of traffic is one way in the morning and the other way in the evening, and speaking generally it is desirable to have the power at times of sending a succession of trains following one another in the same direction without waiting for return trains.

To get over this difficulty, the 'train staff and ticket' system was devised. This system allows a station-master to give a ticket to an engine-driver instead of delivering to him the staff, provided that he exhibit the staff to the driver when he gives him the ticket. Thus any number of trains may follow one another, each with a ticket, and the last train will carry the staff to the other end of the district; and the same operation can be then carried out with the return trains from that end of the district. As a check on the station-master, the staff is sometimes so made that it alone will unlock a special box in which the tickets are kept. The safety of this system is not so great as that of the 'train staff' without tickets, as there is with the ticket system greater opportunity for laxity in carrying out the regulations on which it depends, but it is, nevertheless, a very valuable way of providing for the difficult problem of working single lines with elasticity, and with a near approach to safety.

On some single lines the 'staff' or 'staff and ticket' systems are worked in conjunction with the block system to be now described; they are not, however, necessary adjuncts to the block system for single lines, and some of th

most important single lines in the kingdom have been worked for years with conspicuous success by the block system alone.

Prior to 1842 there was no communication between the different signalling stations, and the only information which an 'all right' signal conveyed to an engine-driver was, that the train which preceded him had passed that particular signal upwards of a specified number of minutes previously. The means adopted for the prevention of collisions in those days was the preservation of an interval of time between trains travelling on the same line of railway, and signalmen were therefore ordered not to exhibit an 'all right' signal until after a train had passed their signal boxes 5, 10, or 15 minutes, as the case might be. It has been already explained (p. 97) that time signalling, though it was for many years found sufficiently good for a light traffic, and has been carried out even with the heavy traffic of later days with considerable efficiency, affords, even when it is perfectly carried out, no real security against collisions.

The introduction of the electric telegraph gave the means of discarding altogether the system of time signalling, and of substituting a system the object of which is to secure the preservation of an interval of space between the trains. The latter system has received the name of the 'Block' system, either from the facility it afforded for blocking the line, and stopping the trains as required, or from the securing or blocking over of the handle of the signalling instrument in the required position, which was necessary in the instruments employed when the system was first introduced. It is by no means a good name, but it has been used so long that probably it will not now be discarded for a better.

The mode in which the block system is carried into effect differs slightly on different lines; that is to say, the machinery by which the signals are transmitted varies, but the principal or object aimed at is the same (with one exception, to be referred to below) on all English railways. The

exception referred to is what is called the 'permissive block' system, the operation of which will be explained after the ordinary or 'absolute block' system has been treated of.

To carry out the block system a railway must be divided into a certain number of telegraphic districts by signal boxes, in each of which there are signalling instruments, enabling the signalman in it to communicate by electricity with the signal box on each side of him. Thus, supposing a line is divided into four districts by signal boxes A, B, C, D, E (fig. 114), A will communicate with B, B will communicate with A and C, C with B and D, D with C and E, and E with D.

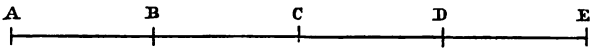


Fig. 114.

The districts may be of equal or unequal lengths, as may be convenient for working the traffic. Supposing, then, that a train is ready to start from A, the signalman at A will warn B of the fact. B will acknowledge the signal, and say 'send the train,' which A will do by lowering his outdoor semaphore signal. A at the same time will notify to B that the train has left; B will acknowledge the signal and will at the same time give some sort of signal in the signal box at A, which will notify to A that no other train must be sent until further orders. This last operation is called 'blocking the line.' As soon as the train has arrived at B, the signalman there will notify A of its arrival, and will 'take off' the block signal and give 'line clear.' Precisely the same series of signals passes between every signalman from A to E, excepting only that at the intermediate signalling stations between A and E the signalman may in some cases send on the warning signal which he receives to one or perhaps two stations in advance, so as to avoid any necessity of checking the speed of such trains as have to pass the stations in question without stopping at them.

Now supposing that a train breaks down or is delayed between C and D (fig. 115), and that a train is ready to

start at A. C will have asked permission from D to dispatch the train subsequently disabled, and as soon as this has

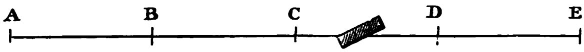


Fig. 115.

been done D will have blocked the line at C. This block cannot be taken off by C, or indeed by anyone but D, who will not do so until the disabled or delayed train reaches and passes the signal box at D. Meantime, supposing that the second train is travelling between A and C. When it arrives at C the engine-driver will find the signal at 'danger,' in obedience to the orders of D, and will consequently pull up at C. C has previously blocked the line at B, when warned that the second train has passed B, and has thus protected the second train from being run into by a succeeding train starting from A. In this way, in the case of a break-down of a train between C and D, if trains continued to be despatched from A, the condition of the line would be represented by the sketch below (fig. 116); when this state of things has occurred, no more

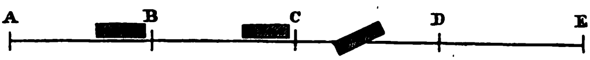


Fig. 116.

trains could be dispatched from A until the disabled train between C and D had been removed. Thus, however heavy the traffic might be, and however rapidly trains were dispatched from the terminus of a line, still so long as the block signalling be systematically carried out, no collision can take place, because an interval of space equal to the length of each district would be preserved between the trains.

The first suggestion of applying electricity to working railway traffic appears to have emanated from Sir W. F. Cooke, in the year 1842, when he published a pamphlet entitled 'Telegraphic Railways,' in which all the leading

principles embodied in the present block system were enunciated, besides some others which have not yet been adopted, but which are very desirable. In 1844 a length of line on the Eastern Counties Railway was signalled electrically, but public opinion was then not sufficiently educated in the advantages of the electric telegraph; and though it is believed that the experiment was eminently satisfactory as a first effort, the system was objected to on the score of expense, and the whole subject of electric signalling as a system for the ordinary working of a railway slumbered for some years.

Meanwhile the amount of railway traffic was increasing, and with the increase came some terrible collisions in tunnels and other dangerous places, by which it was made evident that the time system of train signalling was radically faulty. Gradually, the electric telegraph was resorted to for signalling on single lines of railway and in specially dangerous places; the new system of electrical signalling soon won its way as an exceptional arrangement for particular places, and from that time the application of the block system to railway traffic in general became rapid.

In 1851 Mr. C. V. Walker, the telegraph engineer of the South-Eastern Railway Company, introduced a system of signalling trains by bells struck by a hammer actuated by electricity, and for upwards of 12 years the trains of that company (to whose officials high honour is due, as being almost the first to thoroughly appreciate the merits of the block system) were worked exclusively by audible electric signals. The bell signalling was eminently successful, and indeed is still the back-bone of electric signalling. The audible electric signals have been gradually supplemented by visible electric signals, which will be described below; but though visible signals are extremely useful in all cases, and particularly where the number of trains to be signalled is large, they are not a necessity even to a complicated system of traffic, as may be seen from the fact that upwards

of 500 trains were often signalled by two bells, in a busy day, on the South Eastern Railway.

Before referring to the visible electric signals, it will be well to describe the audible system, as it existed prior to their introduction. Any number of signal boxes for a double line of railway, A, B, C, &c., being connected together by electric wires and being furnished with galvanic batteries, two bells (fig. 117), of dissimilar sounds, are placed in each intermediate box, and in each signal box two spring buttons or, as they are technically called, 'keys' (fig. 118), are fixed. The key is the means by which the circuit of an electric wire is made and broken. A spring keeps the key outwards in its normal position, but a slight pressure of the hand

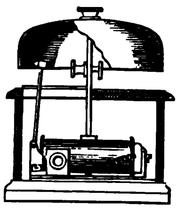


Fig. 117.
Electric bell.

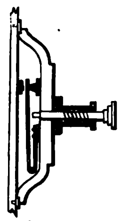


Fig. 118.
Electric key.

forces the key inwards against the pressure of the spring. Each time the key is pressed inwards the circuit is made, and the bell connected with the wires is caused thereby to ring once. Thus to give a certain number of strokes on the bell of a distant signal box, the key must be pressed inwards that same number of times. In the first box A, and the last box Z, there would be only one bell and one key. Taking the case of the signal box B, there would be two keys, one of which rings a bell in A and the other a bell in C; but the signalman at B has no power over the two bells in his own box, one of which is rung by A, and the other by C, and one bell applies to the up line and one to the down line.

There is a stringent rule that every signal shall be repeated from the recipient of the signal back to the giver of the signal, so that there may be a close understanding between both parties, and that the giver of the signal may have proof not only that the signal which he sent has been received, but also that it has been rightly understood. An ordinary bell code is as follows:—

One blow for every up train	*out.*
Two blows for every down train.	*out.*
Three blows for every train	*in.*

Such is a code of the simplest description for train signalling; but in addition to this, there would be other signals, viz. five blows to notify that the line was obstructed, six blows as a testing signal to see whether the apparatus was in working order, and other signals of a similar kind. Further, in many cases it is found necessary to distinguish, by the bell code, between different descriptions of trains, and gradually a bell code came to involve a much larger number of blows on the bell for signalling trains than the few signals described above.

Taking, however, three signal boxes, A B C, and applying to them only the simple code, running up to three strokes on the bell, and assuming that the first down train of a day is ready to start from A, the signalman at A gives *two* beats on the bell at B, to apprise the signalman there that the train is ready. B gives two beats to repeat and acknowledge the signal, and A then starts the train by lowering his outdoor semaphore signal. A then gives *two* beats a second time on the bell of B, to say the train has started, and B acknowledges the signal by *two* beats. The first *two* beats given by B, however, block the line, and mean in words 'I understand that a train is on the line between A and B, and no other train must be allowed to pass A without my further orders.' When the train has reached B, the signalman there gives *three* beats on the bell of A, to say 'the line is clear

between A and B, and I am ready to be notified that another train is ready'; this being acknowledged by *three* beats from A, the series of signals for the first train is complete as between A and B. While the train is passing between A and B, B will signal forward the warning signal of *two* beats to C, and if C replies by *two* beats, B will lower his outdoor semaphore signal before the train reaches B, so that its progress may not be checked; otherwise, and unless he receives *two* beats from C, he will detain the train at B by his outdoor signals.

It is a most important condition of any such code that no signal shall be considered as having been given, or shall be acted on, until it has been acknowledged and repeated, and it is of especial consequence that this rule should be rigidly enforced with a code of signals which are exclusively audible. When the combined system of audible and visible signals is considered, it will be seen that it is not of the same consequence that the signal should be repeated; and in such cases a common acknowledgment signal is generally used, applicable to all signals given, and the special audible signal is generally not repeated.

All signals should be registered in a book as soon as they are received, with the exact time of their having been given in one signal box and received in the other. A telegraphic signal giving true time should be given to all signal boxes at least once a day, so that the clocks may all tell one tale, and the registers of the signals agree together.

In many places, such as at level crossings of roads over railways, it is desirable to intimate to the gate-keeper that a train has left the preceding station, though his duty is not to telegraph the trains. In such cases a bell is placed in the gate-keeper's hut, in electric connection with the bells in the signal boxes on each side of the crossing, and every signal is in such case given in the gate-keeper's hut, though he himself sends no signals.

In places where the audible code, from the necessity of

distinguishing between different descriptions of trains, becomes complicated (comprising in some instances, 20 strokes on the bell for one signal), an index or automatic counter, to register the number of strokes given and received, is desirable. It is, however, astonishing how remarkably accustomed the ear of a practised signalman becomes to instantaneously appreciating the number of strokes given, and how rarely mistakes have been made in this respect. But notwithstanding this, an index-counter is valuable, as it affords the check of the eye upon the ear, and should render a mistake in counting almost impossible.

Although there can be no doubt, as the result of the experience of many years, that a well-devised system of exclusively audible electric signals can be worked efficiently, the aid of visible electric signals, which will now be described, is extremely valuable as affording a record of the signal given, which is retained before the eye of the signalman until another signal takes its place.

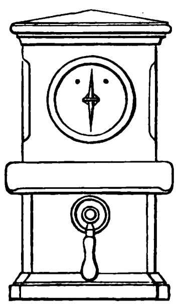


Fig. 119. Electric telegraph needle speaking instrument.

The original instruments adopted for visible electric train signalling were either telegraph speaking instruments, or modifications of them, in which a magnetised needle is deflected to the right or to the left from a central or neutral position, in accordance with the movement of a pendant handle. In the speaking instrument (fig. 119) each letter of the alphabet is expressed by a given number of sideways deflections of the needle, in accordance with a pre-arranged code. In telegraphing trains, however, only two signals are really necessary, viz. 'Line clear' and 'Train on line,' and these were easily given by deflecting the needle for either a long or short time, to the right for one of the above signals, and to the left for the other signal.

When the ordinary speaking instrument was employed for telegraphic signalling, the instrument was not exclusively devoted to the purposes of train signalling, but was also used for conversation, and the words 'Train on line' and 'Line clear' were painted on the dial of the instrument above the alphabet code. To instruments of this sort there were these great objections, viz. that the deflection of the needle was momentary, and no record of its movement was preserved, and that everything therefore depended on the signalman's memory and on his recollection of the time at which a signal was sent, and of the sequence of the signals. A signalman perhaps forgot the fact of a train having been signalled on to his district, and might give an 'all clear' signal for a succeeding train, when the first train had not passed off his district, but was perhaps disabled on it. This difficulty was sought to be overcome by entering all signals in a book; but this is only a palliation of an evil, as signalmen will trust to their memory, and, indeed, can scarcely consult a book systematically in working a crowded line.

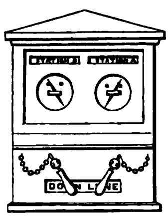


Fig. 120. Train signalling needle instrument.

About 1854, a system was introduced on the London and North Western Railway of setting apart electric instruments which were specially devoted to train signalling, and which were not to be used as speaking instruments. By these instruments (fig. 120) three signals could be given on each dial, viz. 'Train on line,' 'Line clear,' and 'Line blocked.' The two former of these signals were given by deflecting the needle to the right or to the left, by means of the ordinary pendant handles, and a pin was provided to each handle, which could be inserted through a hole in the handle into the fixed frame of the instrument, so as to retain the needle in either position. The third signal, namely 'Line blocked,' was given by the needle being placed in the vertical position, and indicated that an accident

had happened. This last signal could not only be given from each signal box, but could also be made by cutting the telegraph wires, and provision was made for this to be done at numerous spots on the line, intermediate between the signal boxes, by bringing a portion of the wire down the telegraph posts to within reach from the ground. The guard of any disabled train could thus at once block either or both lines, as the signal could be given to signal boxes on either or both sides of the break-down. This arrangement is only of real use in the case of an accident blocking both lines, and in the majority of cases there would be time to stop a train coming towards the scene of the accident by flags, lamps, or fog-signals, if it had not already passed the signalling stations to which the 'line blocked' signal would be given by cutting the wires. If the train had passed the signalling stations the signal would of course be useless to it. Under the absolute block system, the fact of a train not arriving at the end of a district a few minutes after its entry on that district should be an indication that something is wrong, and this is all the information that was imparted by cutting the wire. Moreover, cutting the wire completely disabled the train telegraph, which, at such a time, might be extremely useful in working a code of signals; and, lastly, it necessitated repairs at a time when they were peculiarly inconvenient.

On the London and North Western Railway, and on some other lines, the 'absolute block' system above described was not at first used, but what is called the 'permissive block,' was adopted, and is still occasionally used. Under it the facility for instantly informing the signalmen of a break-down might no doubt be useful. Under the 'permissive block' system no signalman is allowed to give an 'all right' signal to an engine-driver till he has received a signal of 'line clear' by telegraph from the next signal box; but he is not to altogether stop a train succeeding one already *on his district*, but to arrest it temporarily, and, after warning

the engine-driver that the line is not yet free, allows him to proceed. This system permits, consequently, two or three trains to be on one district at a time, and is much inferior to the absolute block system.

The needle instrument is still retained on many lines for train signalling, but the third signal of 'Line blocked' is generally discarded; the vertical position of the needle now usually expresses the fact that no signal is at the moment being given, and that for the time being all electrical signalling is in abeyance. As a matter of signalling, this last-mentioned third signal is not desirable. A line is either clear or it is not clear, and the only advantage of the neutral position of the needle is, that with certain descriptions of instruments it avoids an expenditure of the power of the galvanic battery, which is not a matter of much consequence as the expenses of a battery are small.

The above description of instrument was no doubt, when it was introduced, a great improvement, and electrically possesses some advantages compared with the more modern apparatus; but, in point of convenience and in rapidity of signalling, it is not so good as the instruments subsequently introduced, while it is open to the objection that it is more easily used than other instruments for unauthorized conversation between signalmen.

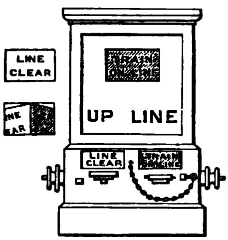


Fig. 121. Needle instrument with card.

In other instruments of a similar description—introduced many years subsequently (fig. 121)—a small piece of card is attached to the needle, and on one side of the centre of the card are the words 'Train on line' on a red ground, and on the other side 'Line clear' on a white or green ground. A hole, large enough to disclose at one time half the card, is cut in the face of a dial fixed in front of the needle, and thus, by deflecting the needle to the left or the right, the

words 'Train on line' or 'Line clear' are in turn exhibited through the hole in the dial. The third signal is, in such cases, given by the needle being put in a vertical position, when half of one inscription and half of the other appear particoloured through the hole. The needle which carries the card is either moved by pendent handles, similar to those of the speaking needle instrument, with pegs for blocking over the needle, or by means of spring buttons, which are pressed in by the signalman's hand, and are retained in their position by a pin. There is little difference between this instrument and the former, but it is perhaps slightly more distinct in the information which it conveys. The difference between the two is much the same as that between an ordinary needle compass, in which the needle points to divisions on a fixed card, and a mariners' compass, in which the card is mounted on the needle, and travels with it.

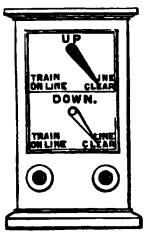


Fig. 122.

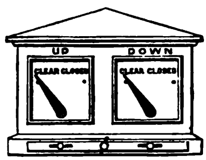


Fig. 123.

Electro magnet needle instruments.

About 1852 some instruments (figs. 122 and 123), worked by electro magnets, were introduced for train signalling, and have since been much used. The object of these instruments was, like those above mentioned, to supplement the bell code of signalling, and to appeal to the signalman's eye as well as to his ear, but they claimed to do this in a more convenient way. The mode in which they are used is as follows. When the warning signal is given

from A to B that a train is ready to start from A, the signalman at B, in acknowledging it ,and giving the signalman at A permission to start the train, presses a button, which not only rings a bell, but also moves the needle in A's box which was pointing to 'Line clear,' and turns it to 'Train on line.' A must then detain any train following the train in question until B has not only given the signal 'Line clear' on the bell, but has also turned the needle to 'Line clear' on the dial. There are two needles for each line in each signal box, which are painted respectively red and black. The black needle shows the last signal received at any signal box, and the red needle shows the last signal sent from the same signal box. Thus a signalman has before him not only the order sent to him from a distant signal box, but also a record of the order which he himself has last sent to the other signal box. The black needles can only be affected by currents of electricity sent from another signal box, and the signalman in whose box they are placed cannot alter their position.

It will be observed that there is a seeming contradiction in this system of signalling in the signalman at B replying to the request of the signalman at A for permission to send a train by saying on the bell signal, 'Yes, send the train,' but turning the needle at the same time to the prohibitory signal of 'Train on line.' This contradiction is more apparent than real, and is not found to lead to mistakes in working. The important part of the block system is to promptly block the line behind a train to prevent another following it till the first train gets clear of the next station, and it is better to do this even before the first train passes than to delay the signal for the time necessary to send another signal to say the train has passed. At the same time it cannot be denied that it is undesirable in any system of communication to have signals which, for however short a time or however well understood, state that which is not the case.

An electric miniature semaphore signal, shown on fig. 124, was first introduced in 1855 on the South Eastern Railway, to fulfil the same purposes as the needles above described. The point aimed at was to use a signal which should be identical in appearance with the outdoor semaphore signals, so as to make electric signalling the counterpart of the outdoor system. The necessity for visible signals to supplement the audible signals was, however, not greatly felt on the South Eastern Railway, on which the bell code had been very efficiently conducted till the opening of the Charing Cross Extension of the South Eastern Railway in 1864 caused a great concentration of traffic, and directed attention to the miniature semaphore as a most useful adjunct to the audible system.

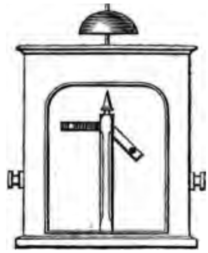


Fig. 124. Miniature electric semaphore (two arms).

The electric semaphore signal which is now extensively used on many lines is a post with two arms for each line of rails; and the arm on one side of the post is painted red, and the other arm white. The red arm is the means by which the signal is received from a distance, and the white arm is an indicator of the signal last sent. There is a key (fig. 125) for working the semaphore signal, similar to the key used for sounding the bells; but it is double, and possesses two knobs, which are respectively black and white. By pressing the white knob at B, the red semaphore arm at A is lowered, and at the same time the white arm at B is lowered, in agreement with the movement imparted to the red arm

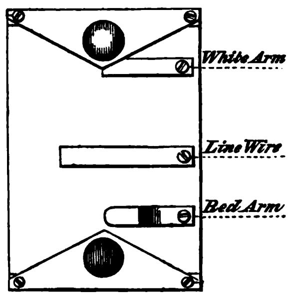


Fig. 125. Electric semaphore key.

at A. At the same time the bells are rung in accordance with any prearranged code, but the instruments are so made that when it is necessary to give 5 or 6 blows on the bell to describe the nature of the train about to pass, the first blow alters the position of the semaphore arm if necessary, and the subsequent blows do not affect its position. Conversely pressing the black knob at B raises the red arm at A, and the white arm in the box at B.

Thus, supposing a train has to pass from A to B, A warns B by the bell that the train is ready, B acknowledges the signal on the bell, and in effect says 'Send train.' At the same time he puts up the red miniature semaphore arm in A's box to stop all succeeding trains, while the rising of the white arm on his own miniature semaphore reminds him that he has sent the signal. As soon as the train reaches B, he telegraphs the fact by 3 blows on the bell, and at the same time lowers the red arm at A and the white arm in his own box, ready for another train.

It is convenient that the miniature semaphores should be placed so as to face the signalman from the direction of the next signal box with which they are in communication. Thus an electric semaphore communicating with a signal box to the west of B would be placed on the west side of B's signal box, and that communicating with a box on the east would be placed on the east side of B's signal box. The miniature semaphores are extremely simple, not liable to derangement, and tell their own tale in a most efficient way.

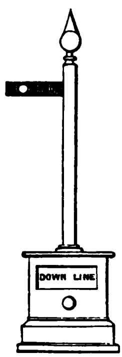


Fig. 126. Miniature electric semaphore (one arm).

A form of miniature semaphore, but worked by means of three wires to each instrument, instead of one wire as above described, and with only one arm (fig. 126) instead of two arms, was introduced by Mr. W. H. Preece, and was largely adopted on some railways.

This miniature semaphore is worked by a switch handle (fig. 127), resembling the lever by which the outside semaphore arms are raised and lowered, and a separate single key is used for ringing the bell. The acknowledgment of

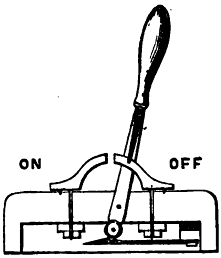


Fig. 127. Electric switch handle.

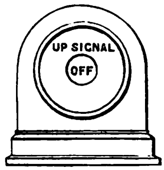


Fig. 128. Electric indicator dial.

the signal sent is given on a dial (fig. 128), on which the words 'on' and 'off' appear, in agreement with the position of the semaphore arm at the distant station. It is in the visible acknowledgment of the signals sent that the peculiarities of the three-wire system consist; and, although the system is somewhat more expensive, and introduces some undesirable complications, it possesses some undoubted advantages. One great necessity of telegraphic signalling is, that the signals sent should be correctly acknowledged, and that a signalman at A should not have it in his power to mistake and acknowledge a signal of 'Train on line' sent from B, as being a signal of 'Line clear.' With instruments worked by one wire it is true that the visible signal is exhibited both in the cabin of the sender and of the recipient, but there is no absolute security that the recipient has correctly received the exact signal despatched by the sender, nor that a signal may not have been altered by some defect in the electric circuit between the two cabins. The mere acknowledgment sent back by the recipient by a beat on the bell, which is the audible acknowledgment for all

signals, only means that a signal has been received, and it is possible, though improbable with the present powerful instruments, that a false signal has been sent, and that when B meant to raise the semaphore at A, he has, from some cause, not raised it as he intended to do.

This difficulty is met by the three-wire system in the following way, to explain which the case of the two signal boxes, A and B, must be again considered. The miniature semaphore is so made and so connected with three telegraph wires, *x*, *y*, and *z*, that when the miniature semaphore arm is raised at A by the signalman at B, the wires *x* and *y* are placed in contact by the same mechanism that raises the miniature semaphore arm. An electric circuit is made by the contact of *x* and *y*, which enables a signal to be given by A to B which will correctly acknowledge the particular signal sent by B viz. that of the raising of the semaphore arm, and will acknowledge no other. When the acknowledgment of the signal is given by pressing the bell key at A, a current will pass to B, which will ring a bell at B, and turn the indicator at B to the word 'on,' but which cannot turn it to the word 'off,' nor allow it to remain at the word 'off.' Similarly if the semaphore arm is lowered at A, the act of lowering it disconnects the wires *x* and *y*, and puts the wires *y* and *z* in contact; a different circuit is thus completed, and by this circuit, when the same key at A is pressed to acknowledge the lowering of the semaphore arm at B, the word 'off' can only appear on the indicator at B, and the word 'on' cannot appear. In this way a signal cannot be acknowledged except in the sense in which it was sent, and in the way in which it is visibly exhibited in the cabin of the recipient.

It is right to remark, however, that the danger apprehended and guarded against by the three-wire system has not been found to exist to any serious extent, and that though theoretically more perfect than a system worked by one wire, the three-wire system is exposed to the disadvantages of

increased complication of mechanism and of considerable extra expense.

In some situations it is necessary that a signalman shall communicate with and instruct a signalman intermediate between himself and the signalman with whom he ordinarily communicates, but who does not work a block district. This sometimes occurs in the case of sidings, which are only occasionally used. In such a case the switch handles (fig. 127), which work the miniature semaphores, are connected together both at the main station and at a signal box at the sidings in a mechanical apparatus similar to the locking apparatus of the point and signal levers, so that the signalman is not able to move the miniature switches, and so signal to the sidings that the points there may be used, until he has first put the switch handle of the miniature main line semaphores at the next block signalling station at 'danger;' and conversely, that he cannot move the switch to lower the main line miniature semaphore until he has first put the miniature semaphore at the siding to 'danger.'

A very useful instrument called a Train Describer, and shown in fig. 129, has been recently introduced by Mr. C. V. Walker. Its purpose is to simplify the bell code, and get rid of many complex audible signals in signal boxes where it is necessary not only to describe a train as an 'up' or 'down' train, but to tell the signalman, in advance, from what place it is arriving or whither it is going. Thus, on the Cannon Street line of the South Eastern Railway, where this train describer is in use, it is necessary to discriminate between no less than eleven sorts of trains, and to do this on bells entails an inconvenient amount of ringing.

The train describer has a dial which is usually fixed below the ordinary electric semaphore, which is worked as above described, and on the dial there are a number of names (corresponding to the number of descriptions of trains using the line) painted in small circles near its circumference. A large needle like the hand of a clock is worked by electricity

from the next signal box, and points to any of the names on the same principle as that of Sir C. Wheatstone's A B C telegraphic speaking instrument. Each complete apparatus consists of two describers, one the sender and the other the receiver. The sender instrument is furnished with small mov-

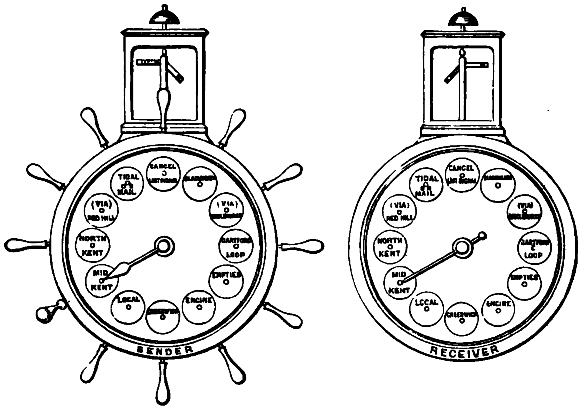


Fig. 129. Train describer.

able handles placed radially outside the circumference of the dial, and opposite to the small circles containing the names of the trains. When the instruments are to be used, the signalman gives a warning signal on the bell, and if, for instance, an 'up Mid Kent' train is coming, the handle opposite those words is pulled forward on the up sender instrument, and the needles both on the up sender instrument at signal box A and on the up receiver instrument in signal box B, point to 'Mid Kent.' The signalman thus has a visible record of what kind of train is coming; he has not to trust to his memory at all, and an immense amount of ringing is avoided.

It will be observed in fig. 129 that the signal at the top of the dial is to cancel the last signal, and this is used in case of an error having been made in describing a

train. It is a question whether the dial of the train describer ought not to have a zero in addition to the cancelling signal, and whether the giving the 'all clear' signal might not with advantage put the needle back to zero, instead of allowing the needle to remain at the name of the last description of train, long after that train has passed. This is a small matter, and might easily be arranged if in practice it be found desirable.

Some of the most important of the means of carrying out the block system have now been described, but no doubt there are many other modes, either at present in use, or likely to be invented, for attaining the same ends. The system still admits of improvement, and advances will probably be made in connecting the electric signals with the outdoor signals, so that the instructions of a distant signalman may be communicated with certainty to the driver.

Several plans have been suggested for enabling signalmen to exhibit signals on the engine itself; and, indeed, the mere exhibition of electric signals on the engine has been practically carried out in the electric train telegraph, which gives communication between passengers, guards, and engine-drivers, and which will be referred to hereafter in the chapter on rolling stock. An arrangement has also been worked out experimentally, by which every train can automatically carry out the block system, and can give and receive signals to and from the engine as it passes along the line. However well this system may be carried out, it will not probably dispense with signalmen by the side of the line, and with the use of fixed signals. A signalman is useful not only as an exhibitor of signals, but as a watchman over the signals, to see that they work correctly, and over the trains as they pass, to detect anything that may be wrong in them ; and it is in the highest degree desirable that there may be persons at specified places who can act in an emergency with experienced intelligence. For these reasons automatic signals, whether

outdoor signals or electric signals, have never yet been found to be a satisfactory substitute for signalmen, while further they are exposed to the drawback that their mechanism may break down at the most important moment, and that defects in their working may not be discovered till a disaster has occurred.

The above remarks do not, however, apply to any system which, without dispensing with the superintendence of a signalman, should render it impossible for him to exhibit an outdoor signal contrary to the orders of the miniature electric signals in his cabin; and it must be remembered that, at the present time, it is by the outdoor signals which are seen by the engine-drivers, and not by the telegraph signal, which is inside the signal box, that a train is actually controlled. At present a disagreement may occur between the electric and the outdoor signals, and there is no actual certainty that a signalman obeys the orders of another signalman, who may be perhaps four or five miles distant, but to whose orders, expressed by the telegraph, it is his duty to conform. In the case of an outdoor signal, as explained above (Chapter IV. p. 111), it has been rendered impossible for disagreement to take place between signalmen who by mechanical means jointly control a signal though it may be perhaps 1,000 yards distant from one of them; because, by means of the slotted signal rods, the combined assent of any number of men may be necessary for the movement of the signal. The same sort of control over a signal removed in this case to any distance from one of the signalmen, has been attained in what is called the 'electric slot signal' (fig. 130), which is a promising contrivance, though it has not yet been carried much further than experimental working. The title has been probably given from the similarity of results attained by the mechanical and electric slot; but in all other respects it is an inappropriate name, as the arrangement of the slot forms no part of its mechanism.

A is a lever consisting of a pair of wrought iron plates side by side, with a space of about three inches between

them. This lever is worked by a connecting rod from the signal lever. C is a clutch pivoted to A. H is a hammer so pivoted that a small upward movement of A will raise H to the nearly vertical position in which it is shown in the figure. S is a lever working on the same pivot as A, and works the signal. When S is free, and not held up by the clutch C, the signal flies to 'danger.' M is an electro-magnet, and *d* a detent.

When M is magnetised by a current of electricity from the station in advance, the hammer H is held in its vertical position by attraction to M, and is further secured by the detent *d*, also worked by the electro-magnet M.

The maintenance of a current of electricity by magnetising M holds up H, but if the electric circuit be broken, the electro-magnet M ceases to hold up H, which then falls by gravity on to the upper end of the clutch C, thus releasing the bar S, which is held by the clutch C, and allows the counter-weight of the signal to place the signal at 'danger.'

The clutch C is so weighted as to catch S unless H is lying on the upper end of the clutch; in that case A may be moved up and down, but the clutch will not grasp S, which will in such case be unaffected by the movement.

The signalman in advance can thus, by breaking the electric circuit, prevent H from being held up, and by so preventing the clutch from holding up the lever S, he can take away from the signalman at the signal lever all power of lowering his signal to 'all right.' Similarly if the signal is at 'all right,' the signalman in advance can at any moment release the hammer H, which falling on to the clutch, puts the signal at 'danger.'

It will be observed that the advantages of the locking apparatus need not by any means be dispensed with in the apparatus of the electric slot, and the main lever shown in the sketch may be supposed to be one of a number of signal levers placed in an ordinary locking frame and interlocked with the point levers. It in fact carries out

by means of an electric current—which can be conveyed to any distance by means of an ordinary telegraph wire—the

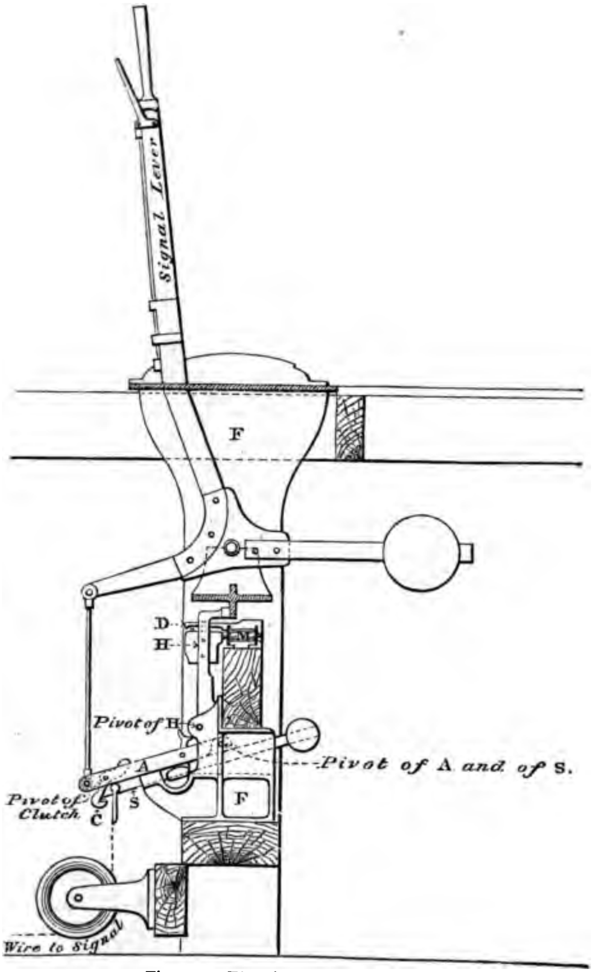


Fig. 130. Electric slot signal apparatus.

principle of the mechanical slot (which owing to the difficulties involved in the use of long connecting rods or wires, cannot be applied to signal boxes further distant than about 1,000 or 1,200 yards), in so far that neither of two signalmen can lower the signal to allow a train to proceed without the active consent of the other, but either of the two can at any moment put the signal to 'danger,' and can keep it there.

A point on which some difference of opinion exists among railway managers is the question whether or not a telegraph speaking instrument should form part of the furniture of a signal box. It is said that a speaking instrument is apt to induce a want of stringency in working the block system, as a signalman, if a train does not arrive when he expects it, will begin to talk to the next signalman as to the reason of its non-arrival, and may produce some accident, from want of complete knowledge of what is happening elsewhere; and that all that a signalman ought to do in case of delay in the arrival of a train is to keep the line behind him blocked, and he ought not to have it in his power to modify the working of the block system in the slightest degree. Further, it is urged that if speaking instruments are given to the men, they will be used for idle conversation when the men ought to be attending to their duties.

There is no doubt some force in both these objections but not enough to outweigh the advantages of having telegraphic speaking communication. The second objection viz. unauthorised use of the speaking instruments might be counteracted by mechanical contrivances which would leave a record of the instrument having been used, and render necessary an explanation of its use to the inspector when he visits the signal box.

The first objection, which is more serious, may be partly met by careful regulations as to what is to be done in the case of a break-down, and a strong standing order that in no case is a signalman to relax the block system except

under the orders of an authorised inspector. The advantages of speaking instruments are very great, and they have in many cases prevented serious accidents by warning the next signalman of defects observed in the permanent way by an engine-driver, or of something seen to be wrong in the rolling stock and detected by the signalman as a train passed by. In the event of a train on an incline breaking in half, it is in the highest degree useful that there should be means of warning the station at the bottom of the incline, so that those in charge there may be prepared to deal with runaway trucks. In the case, too, of an accident taking place, it is highly desirable that the particulars of the accident should be forwarded with the least possible delay to headquarters, so that the necessary steps may at once be taken for the relief of the sufferers, and for clearing the line. Next there may be defects in the electrical instruments working the block system, and the speaking instrument may then, under a code specially contrived for the purpose, take their place for a short time, in which case, however, every message should be written down by the sender, and both written down and repeated by the recipient. In case of illness also of a signalman, and indeed, in numberless other instances incidental to the traffic of a railway, speaking instruments are extremely useful, and can only be dispensed with at the cost of great inconvenience. Speaking instruments ought therefore, it is believed, to be supplied to signal boxes, but their use should be narrowly watched.

The want of supervision of what goes on in distant signal boxes is no doubt felt by all railway managers, and a tell-tale arrangement has been devised, to record automatically the events of every day. A paper revolving on a time cylinder, driven by the clock of the signal-box, is so connected, electrically or mechanically, with the block system instruments, the speaking instruments, the point and signal levers, and by a treadle with the trains passing the signal-box, that every movement of signals and of trains is recorded

on the paper cylinder at the exact time at which it takes place. A fresh paper can be placed on the cylinder every morning, and the old paper sent to the inspector of the district. By some such means it would be possible to see not only what the signalman did, but also to know whenever any and also which engine-driver ran past a 'danger' signal, without placing on the signalman the responsibility, which is sometimes shirked, of reporting such irregularities.

Viewing, then, the block system as a whole, it may be safely said that it has the advantage of being perfect in principle in so far that it renders collisions impossible provided it be carried out perfectly ; whereas the system of time signalling, even granting that it can be carried into effect without a flaw, gives no absolute security against collisions.

The difference between the two systems, then, is not one of detail, but of kind ; and the questions of importance which have to be considered in judging of the applicability of the block system to particular lines and to railways in general, are: (1) can the block system be carried out with sufficient perfection? (2) does it induce other dangers from which other systems are free? and (3) to what extent does it impede the traffic? With respect to the first of these points, it may be stated without fear of contradiction that the block system can be carried out with a nearer approach to perfection than any other known system of signalling. Perfection, however, has not yet been attained for the simple reason that the system is at present dependent on the intelligence, care, and obedience, of signalmen and engine-drivers, and although no words can as a rule be too strong to express the trustworthiness of this valuable class of men, yet human nature is not perfect, and occasionally even the most tried and steady men may make a mistake in a duty which they thoroughly comprehend, and perhaps have fulfilled without error for years. This objection—viz. its liability to failure from human fallibility—is frequently urged against the block system, but it really is not an objection against that system

in particular. It applies to every other known system of signalling, excepting only an automatic arrangement of signals by which trains should signal themselves. A purely automatic system, however, implies absolute reliance on machinery which may get out of order, and which cannot deal with emergencies as an intelligent and experienced signalman can do. The great object to be aimed at is to simplify the task which each signalman has to perform, to arrange that every signal made between two signalmen should be checked in order to ensure its having been correctly given and correctly understood, and to simplify the transmission of signals between the signalman and the engine-drivers. Thus, in answer to the first question, it may be stated that the electric telegraph supplies all that is required to make the block system sufficiently perfect for railway signalling, though as yet perfection has not been obtained in the means by which the block system is carried out.

The second suggestion, that the block system introduces new dangers, which is the heaviest charge against the system, is endorsed by some few railway authorities, brought up under the old system of time signalling. They accuse the block system of inducing among engine-drivers a feeling of security, which makes them run carelessly from signal station to signal station, without keeping so sharp a look-out for chance obstructions as they formerly did; and they assert that, consequently, the general level of care and intelligence in engine-drivers is being gradually lowered. It is probably true that engine-drivers proceed at a higher speed in thick weather under the protection of the block system than formerly, but the increased safety of the system justifies them in so doing. It must be borne in mind that engine-drivers are generally the first to suffer in a collision, and that there is no reason to suppose that they are more careless of their lives and limbs than other folks. If the block system has made such men feel a security which they did not feel before, it is fair to assume that it must be because it has been found

to be safe, compared with other systems, by the very men who are most interested in its merits and demerits and who are well qualified to form a sound opinion thereon.

Engine-drivers are fully aware of the danger of chance obstructions, or defects in the road, and it is probably a mistake to suppose that they do not now-a-days keep as good a look-out as ever they did. But, as this matter is one which is much discussed, it is as well to try to understand what safeguard a good look-out gives, when compared with efficient signalling, and what are the chances of attaining any safety worthy of the name under the modern conditions of railway traffic by the best look-out, combined with imperfect signalling.

A train travelling at the rate of a mile a minute, can, with ordinary break power, pull up in half a mile, and on a clear day and on a straight line of railway, the engine-driver can see for about a mile in front of him. If he sees a vehicle a mile off, he must, therefore, at once make up his mind whether it is on his own line or not. If the line be curved, it is extremely difficult, till one gets near to a train, to tell on which line of rails it is standing; while, further, on the clearest days an engine-driver has to contend with the obstruction of view caused by steam from his own or other engines. If the above is the case on a clear day, the chances of attaining safety by a good look-out in thick weather, on a dark night, or in a tunnel half full of smoke, are very much less. The fact really is, that the safe conduct of railway traffic depends, and must depend, on good signalling, which will prevent trains from overtaking one another, and that any systematic reliance on a good look-out to make up for the shortcomings of signalling would, with the traffic which our lines now carry, be ruinous. The look-out for signals of all sorts must be of course the best, and engine-drivers must be prepared for unexpected signals in cases of exceptional difficulty, such as, for instance, a defect being suddenly discovered by platelayers in the permanent way.

In such a case reliance ought not to be placed on an engine-driver seeing a small flag or a dim hand lamp, but fog signals ought to be freely used as well. But these instances should be quite exceptional, as in ninety-nine cases out of a hundred, when the progress of a train has to be unexpectedly arrested, owing to the breakdown or delay of a preceding train, it will be effected under the absolute block system by the ordinary standing signals, at places at which signals are as a rule exhibited, and this is not necessarily the case with time signalling, or with the permissive block system.

The trains which use a line of rails in a day at the present time on the main lines of traffic are, in many cases, double or treble the number which used the same rails in the same time twenty-five years ago; and though, perhaps, the speed of fast passenger trains has not much increased of late, the variety of trains is much greater. On such a line as the London and North Western, between London and Rugby, there are at the present time sixty-four through down trains a day, all of which travel for part of the distance over one line of way. These trains include among them express passenger trains, stopping at no station between London and Rugby, slow passenger trains stopping at nearly all stations, express goods trains, slow pick-up goods trains stopping at all stations, mineral trains, and parcels trains. On portions of the Midland Railway there are nearly twice as many similar trains on each line of ways. Such an amount and variety of traffic could not have been carried on under the time system with anything approaching to the degree of safety which is attained by the block system. And it is probably the fact that, if the use of the block system were to be suddenly suspended, the carrying power of at least the busy parts of our railway system, would be diminished to an extent for which few people are prepared.

The last consideration is, whether or no the block system *is of necessity* so restrictive as to impair the carrying power *of the lines.* It must be admitted that any system of

signalling which could be devised must act at times as an impediment to a free and unrestricted use of a railway, for rules cannot be at once stringent and elastic. It is of more consequence that the rules regulating railway traffic should be stringent, so long as they are sound, than that now and then a train should be delayed, if the delay does not lead to a collision. But the question is, does the block system, when properly carried out, of necessity impede the conduct of traffic? On a fair consideration of the whole question, the answer must be in the negative. The Metropolitan Railway Company work trains at the rate of 18 per hour on each line of rails, or with average intervals of $3\frac{1}{3}$ minutes between trains, and the minimum interval is considerably less. The District Railway Company and the South Eastern Railway Company on the Charing Cross Railway have about the same number of trains per hour on a line of rails; and many other similar instances could be given. It seems difficult to understand how a system which allows of such an enormous amount of traffic being worked safely on a line of rails, can be considered restrictive compared with any other known system, but it can easily be understood that the application of the block system to deal with so great a number of trains, requires some considerable forethought and pre-arrangement. On the lines to which allusion has been made, the length of the district under the control of each signalman is, in many instances, less than a quarter of a mile, and it is to be remembered that there is no advantage under the block system, so far as safety is concerned, and every disadvantage so far as freedom of traffic is concerned, in making the districts needlessly long. In determining the length of the districts the points to be considered are, how much traffic has to be passed over a line in a given time, and in how short a space can a train, travelling at the highest speed permitted on the part of the railway in question, be with certainty and with a proper regard to economy *pulled* up. Economy is mentioned because there

may be means adopted for pulling up a train in a very short space of time in cases of emergencies, which may be such as produce serious strains and so much wear and tear on the rolling stock or permanent way as to be unsuitable for ordinary application. Where heavy trains habitually travel at 50 or 60 miles an hour, the distance between the signalling stations should be much greater than where the speed is lower. At the present time, even under the most unfavourable circumstances, there ought to be no difficulty in pulling up a fully loaded long train with continuous breaks running on an ordinary line at full speed in 800 yards; if to this distance the length of a long train, say 200 yards, be added, we get the minimum distance required between trains travelling on a main line of rails, where the speed is practically unlimited, and the time taken by quick trains to traverse this distance would be about $\frac{2}{3}$ of a minute.

Trains cannot, however, follow one another so closely as this, as a train will be checked by the distant signal at one station, unless the next block is clear, but making allowance for this it seems, that so far as time alone is concerned, about 50 quick trains per hour might be passed by the block system over such a line, with proper intervals between the signalling stations, provided no other circumstances but the signalling had to be considered; and this number is very far in excess of what is required on any main line. Where the speed is low, as, for instance, on the Metropolitan Railways, and on the lines approaching London, or other large towns, the lengths of the blocks may be greatly reduced. Further, if it be desirable, there may be intermediate block signalling stations to be used for the slow trains and not for the quick trains, so that the length of the block district may be proportioned to the speed of the trains, and the distances between the signalling stations for slow traffic may approach to the lengths on the Metropolitan Railways. Therefore it can scarcely be true, that if a railway be properly divided into block districts, proportioned to the

speed and to the greatest number of trains to be accommodated, the block system is not capable of dealing with any amount of traffic which, for other reasons, is practicable. But it is no doubt the fact that where a railway is not properly divided, or where an exceptionally large amount of traffic is, for a day or two, thrown on a district which is laid out for a much smaller amount of traffic, the result under the block system may be more or less delay. This is, however, a small matter, compared with the safety which the system gives, and can always be rectified either by dividing the line properly, or, in exceptional cases, by temporary arrangements, such for instance as attaching two or more trains together and allowing them to proceed in company.

It is sometimes said that it is unreasonable, if a train is shunting across the line at station A, occupying in the operation perhaps a quarter of a minute in so doing, that the line should be required to be blocked back to B, which may be three or four miles off; but the answer to this objection is (1) that if it is inconvenient it is at least safe, and (2) that if the inconvenience is severely felt, it must be because the traffic of the line is heavy, and the danger therefore considerable, and (3) that the inconvenience can be remedied by inserting an intermediate signalling station.

The question resolves itself very much into a matter of expense, and it must be admitted that the expense of carrying out the block system is a heavy one, entailing, in addition to first cost, the expense of constantly employing the requisite number of extra signalmen, and the annual wear and tear of the apparatus and wires. But the cost of efficient signalling is a remunerative expenditure, both in developing the capabilities of a railway and in preventing those accidents which are not only deplorable to all those concerned in them, but are extremely costly to shareholders in railway companies. The additional expense, therefore (even neglecting all but pecuniary considerations), is not sufficient to constitute a valid objection against this most valuable system.

Before closing this chapter on the Block System, which, with the previous chapter on Signalling, treats of two most important parts of what have been aptly termed 'Railway Safety Appliances,' it will be well shortly to review the aims which should be kept in view in devising and using these appliances.

The objects which it is important should be attained are, (1) that the right 'road' should be properly 'made' and 'kept' for an approaching train, (2) that the right signal should be unmistakably given, and (3) that the signal should be obeyed.

It will be well to consider what is required by each of these three conditions.

(1) As respects the first the signalman must know what is the particular train for which the road is required. This he may tell by seeing some distinguishing mark on the approaching train, by hearing some special whistle given by the train, or by receiving a telegraphic code signal, or one on the train-describer already mentioned.

In each of these there is an opportunity for a mistake to be made; and it would be well if, in addition to the action of the signalmen, a train could automatically signal itself, and this might probably be effected both in the cases of a train at speed and in that of a train standing still waiting for permission to start.

The signalman knowing what road he ought to prepare, proceeds to prepare it, and arrangements have been described in the previous chapter which ensure that the signal for the particular train to advance shall not be given until the appropriate road is made. With regard to these arrangements it may be said generally, that as far as possible they should be such as to give a direct automatic indication of a necessary thing having been actually done, which indication should render it possible for other dependant actions to be performed, rather than that the attempt to perform the necessary thing should permit such other

actions. For instance, in ordinary interlocking apparatus the completed motion of a point or signal lever permits the motion of certain other levers, but it would be better that it should be the completed motion of the points or signals themselves that should liberate the other levers. This was ensured in the crude appliance for simple interlocking, generally known as the wire-lock, where the signal-wire interlocked directly with the point-rod close to the points themselves; but the system of the wire-lock did not admit of extension to meet the requirements of a complicated arrangement of points and signals such as is dealt with in the more concentrated arrangement of the locking-frame now generally used. The principle recommended is carried out in the switch-bolt before described, where the ability of the signalman to move the bolt lever is actual evidence that the points have been correctly adjusted.

The positions of signal arms, as has been explained, can be indicated in the signal cabin by electric repeaters, and this same agency might be employed to control the interlocking. It seems probable that electric indicators of the exact position of the points might be made to serve a similar purpose in the case of the points, so that the interlocking should in effect depend on the actual positions of the points and signals, rather than on the positions of levers which are designed to move the points or signals, but which may have failed to do so.

It has been proposed to liberate self-acting signals at a distance, and even entirely to work distant signal arms by electricity; but the function for which electricity seems especially adapted is to indicate in the signal-boxes the position of points, signals, or of railway trains, and possibly to control the levers of the interlocking apparatus.

It would be feasible with electro-magnets to actuate catches that would directly control the locking apparatus, but it would probably be a sufficient and better plan, firstly that the electric indications should be made so clear that no

signalman could, with his eyes open, propose to move a lever improperly, and secondly that the electric indicators should be made so interdependent and so interlocked with the main-point and signal levers that if the signalman commenced, say by lifting a catch-rod, to move a wrong lever, not only should some distinct audible and visible indication be given that a wrong thing was being done, but a self-acting tumbler or lock should be liberated, that should prevent the mistake from going further than the intention expressed by lifting the catch-rod. In all cases where electrical arrangements such as those suggested are applied, they should be so contrived that a failure in any of the electric circuits should in no case lead to a false 'all right' signal being given.

It would be well to arrange that a signalman should be unable to give any signal other than that appropriate to the train, the approach of which has been announced to him, for if he misunderstands the description of the approaching train and makes the wrong road and gives the wrong signal, there is a danger that the engine-driver of the train may accept this signal as his own, and may run on to the wrong road. Such a double blunder might lead an express train to run into a short siding, or to other similar catastrophes. It must not be supposed that the combination of blunders here suggested is merely the improbable coincidence of two unlikely events, for the first blunder, that of the signalman in misunderstanding the nature of the approaching train, induces the second, namely, that of the engine-driver in mistaking one signal arm or lamp for another. An engineman is perhaps approaching a large station at which he is not to stop; all the signal arms are at danger, and he knows that the arrangements are such that the signalman has been forewarned that his particular train is coming: presently, while advancing towards the station, whistling for the signal to be taken off, he sees a signal changed to the all right position; it is then

not unnatural for him, especially at night, when he sees one out of several red lamps change to green, to jump at the idea that the signal exhibited is the signal for him to run on, for he knows that the signal for the train which he is driving is the only one that the signalman has any reason for giving. Hence the possibility of two men acting erroneously, on the same occasion, must not in this case be rated too low.

It would, therefore, seem desirable that not only should the forewarning and distinguishing telegraph signal be automatic, but that it should control the proceedings of the signalman.

It is further necessary that not only should the correct road be made for an approaching train, but that it should be kept during the passage of that train.

The switch bolt and locking-bar ensures that points shall not be moved during the actual passage of a train over the points, but this is scarcely all that is required. Accidents have occurred from vacillation on the part of signalmen, and there is generally nothing to prevent them, even when the switch bolt is used, from signalling a train to approach, and then rapidly altering the all right signal to danger, when it may be too late for the driver to stop. It seems therefore desirable that after a signalman has given the appropriate signal by lowering his distant signal arm for a train to approach, he should not be able, when once the train has come within easy stopping distance of the signal, to make any alteration in the road he has prepared, which (on the hypothesis that the first-mentioned part of the requirement now under consideration has been carried out), must have been the correct road for that train, until he has not only put the signal to danger, but also until some suitable length of time has elapsed, sufficient to allow the train to stop; when if it has stopped outside the home signal he can proceed to make such other arrangements as seem necessary under the circumstances that led to his changing his mind.

Such a precaution as that here suggested would prevent the class of accidents that may occur at junctions, where a signalman may signal one train to advance, and then not seeing and not thinking that it is obeying his signal, may suddenly signal to it to stop when it is too late to do so; in such an event, and if, at the same time, he invite a second train to advance on some crossing or converging line, the second train may come into collision with the first train which has received an order to stop which it is impossible to execute, and has overrun the stop signal. This occurrence may take place at present, although both engine-drivers may do their duty perfectly, and although no inconsistent signals have been simultaneously given.

(2) That the second desideratum should be carried out, viz., that the right signal should be given, it is necessary, as has been pointed out, that before the 'all right' signal can be given, the road appropriate to the approaching train should be made correctly and secured, and that the signal appropriate to the approaching train should be the only one that can be given. It is furthermore necessary that before the signal can be given there should be certain proof that the line as far as the next signal station is not only made correctly and secured, but that it is 'clear,' that there are no trains or vehicles on it. It has been already explained (p. 126) that it is an essential feature of the interlocking system, however worked out, that before a signal for a train to pass along any road can be given, not only must all signals be put to danger that would invite any other train to 'foul' that line, but all the neighbouring points must be so arranged as far as possible as to divert overrunning or disobedient trains or vehicles from fouling the line which is signalled as clear.

That two trains shall not be at the same time on the same line between the signalling stations is provided for by the block system, which has been so far brought to perfection that such accidents as occur are almost always due

to sheer blundering on the part of the signalmen or drivers. To remove the possibility of such errors it seems desirable that an effort should be made to make the trains automatically indicate their progress; and, that in the event of a signalman endeavouring to give a wrong signal, the automatic arrangement should prevent his doing so. In any such arrangement cognizance should be taken of the tail of the train having passed clear of the block before the line is declared clear. There is at present no sufficient security that a signalman has seen the tail of a train pass him before he gives the signal 'line clear,' and serious accidents have occurred from a train signalled under the block system to advance, running into vehicles that have broken away from a preceding train, and have been left standing on the line.

It is desirable also to ensure that in stations vehicles may not be left standing on roads which are made and signalled as clear for approaching trains. In practice such parts of the line are generally within sight of the signalman; but it is not perfectly safe to rely on this alone, and there are often cases where loop lines and side platform lines are hidden from the signalman by buildings; in such cases it is generally the rule that the signalman should receive instructions either verbally or by mechanical or electric indicators, from one of the station officials at the platform, before he admits a train into such lines, but it would no doubt be better that such information should be given according to some modification of the block system, and that the arrangement should be so far controlled automatically that incorrect information could neither be given to nor be accepted by the signalman.

The block system provides against a train running into a previous train that may have broken down; but it must be remembered that when a train runs off the rails it very frequently fouls the other line, and trains on many railways run so frequently that the guards of a disabled train, even if they are uninjured by the accident, have often not time to

get forward to stop a train on the other line. It is therefore desirable that, as an adjunct to the block system, a signalman who has been warned when a train enters a block, should, if that train does not reach him within a reasonable time, have the means of warning any train in the opposite direction to proceed cautiously.

(3). The last point to be provided for is, that the signal should be obeyed. It has been proposed that if the engine-driver fails to shut off steam and put on the break, that these should be done for him by some mechanism connected with the signals. It would perhaps be feasible to apply some such method at a moderate distance from the signal cabin, which might serve to stop a disobedient or runaway engine sufficiently to prevent serious damage, but one difficulty with regard to any such appliance is, that the point where obedience has to be manifested must be at least as far from the signal station as the distant signal, and any mechanical arrangement for controlling the behaviour of the engine-driver at that distance must be more difficult to work than the mechanism of the distant signal itself, which is often placed as far as it practically can be away from the signal cabin.

It would not probably be difficult to place on the line an electrical arrangement that should indicate to the signalman that a train was approaching rapidly and disobeying his signal, and many arrangements might be suggested by which the signalman could give additional warning to the driver. Fixed audible signals by which an engine-driver may be warned of signals that he has failed to see have been already described (p. 107).

It is necessary, in considering the adoption of any safety appliance, to examine into the probability of its getting out of order, and it is most important, in arranging such appliances, that any breakage or derangement that may take place shall not lead to an accident. If these essentials cannot be secured with an approach to certainty, it becomes

a question to be considered whether, taking all the probabilities into consideration, the proposed arrangement is an improvement on existing methods. It is a truism to say that dangerous safety appliances should not be adopted. It has been already said in this chapter, that the view that the increased confidence due to improved signalling leads to carelessness on the part of engine-drivers, is an argument that deserves but little weight in considering the desirability of improving safety appliances.

If automatic arrangements be adopted, however suitable they may be to the duties which they have to perform, they should in all possible cases be used as additions to, and not as substitutions for, safety machinery worked by competent signalmen. The signalman should be bound to exercise his observation, care, and judgment, and to act thereon; and the machine should, as far as possible, be such that if he attempts to go wrong it shall check him. With the self-recording arrangements mentioned above (p. 164), any such error on the part of the signalman would be detected and investigated; there can be no doubt that one of the most satisfactory ways of investigating the causes of railway accidents and guarding against their repetition is to look carefully into the circumstances of the accidents that nearly happen, and to apply remedies for the defects that may thus become evident.

It must, however, be borne in mind, that in endeavouring to guard against every danger, one can 'buy gold too dear'; for if every possible known precaution is to be taken, regardless of cost, it may not pay to work a railway at all. Not only should economy be studied in the design of safety appliances (and the more costly arrangements are not always the best), but there should be a proper adaptation of the work to the requirements of the situation. Thus precautions which are most necessary for a heavily worked portion of a railway are, on a wise consideration of probabilities, superfluous on a line with small traffic.

It is, however, common to hear the argument that every known means of ensuring safety ought to be everywhere taken. Within limits this is no doubt reasonable, but the concession of the principle must be carefully and largely qualified. It must be borne in mind that the adoption of new appliances in dealing with so complicated a problem as that of working a railway must or ought to be tentative, for there are many promising contrivances which turn out after trial to be unsuitable, and an ingenious plan for getting over one difficulty may produce another and perhaps a worse evil. Moreover, granting that none but suitable inventions are included in the consideration it is simply impossible to carry out literally the demand, that they should all be adopted, for there is no limit, except the cost, to the amount of precautions that might be applied to any railway; and signals, signal stations, and telegraphic checks of all sorts, might be multiplied to any extent, even on the most insignificant branch. The amount and nature of these precautions must inevitably be to some extent limited by the question of money, and the possibility of working a remunerative traffic; and it is thus highly important that whatever money is spent should be spent in a judicious manner, and where it is most wanted, rather than in applying a certain set of precautionary measures uniformly in every situation and all over the railway system.

Improvements in railway safety appliances will be retarded unless a proper subordination of that which is mechanically possible to that which is financially rational, is recognised, and unless the money that is available for the purpose is spent in the best possible manner.

CHAPTER VI.

STATIONS.

THERE are four descriptions of Stations which readily suggest themselves for consideration, viz:—

Roadside Passenger Stations,
Roadside Goods Stations,
Terminal Passenger Stations,
Terminal Goods Stations;

and these will be considered in this chapter in the above order.

Roadside Passenger Stations.

The ordinary class of roadside stations, which will be first considered, is that which is intended for the accommodation of small towns or large villages, at which most passenger and goods trains stop, but through which express trains perhaps pass at speed.

The platform at such a station must not be narrower than a certain width, however small the traffic may be. This minimum width is determined by provision for the safety of persons standing on the platform, when a train passes by or is drawing into the station, taking into consideration the risk of a door of a carriage being at such a time opened, or anything, such as a piece of a tarpaulin hanging loose from a train. The width of platforms should not under any circumstances be less than 12 feet; but it is generally unwise to construct stations at the present time with

platforms so narrow, except in very special circumstances, such as when the station has to be built in a deep cutting or on a high embankment; and a minimum width of 15 feet, with a wider part, say 25 feet, opposite the booking offices, should now-a-days be in most instances adopted (fig. 131) for new roadside stations.

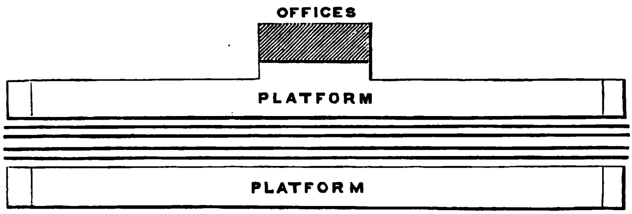


Fig. 131. Roadside passengers' platform, and offices.

The growth of passenger traffic in this country is so remarkable that, even where only a very limited traffic seems probable, provision should be made for a large increase, and the provision in width of platform can be made more easily at first than at any other time. The boundaries of a platform, viz. the retaining wall next the rails and the fences, cost the same for a wide as for a narrow platform, and the booking offices can usually be as well placed 25 feet from the rails as 12 feet. The items of extra expense are therefore the cost of a little more land and the extra quantity of filling and surface of the platforms, and the cost of these are in the country generally unimportant. In towns, although the cost of the land may be great, the importance of forestalling the exigencies of the traffic is at the same time enhanced, as the difficulty of increasing the accommodation of urban stations after the railway is once opened is much greater than in the country.

The length of platforms ought to be equal to that of the longest trains which stop at the station under consideration, and to judge by the almost universal lengthening of platforms which one sees every day, all roadside stations ought

to have platforms equal in length to those of the terminal stations. This length is generally from 600 to 700 feet for main lines of railway, and less for branch lines or for special urban railways, such as the Metropolitan and District Railways. On these railways the platforms are from 350 to 400 feet long, a length sufficient for such trains as are required for Metropolitan traffic, which have to start quickly and can pull up readily and accurately. The Metropolitan Railway was opened with some of the platforms only 213 feet long, but these have had to be lengthened subsequently at great cost. The width of the Metropolitan platforms was originally only 10 feet, but they have been increased to 12 feet 3 inches. Even now the width of the Metropolitan Company's platform is rather under the requirements of the traffic, and this is an evil which will be found more and more serious as time goes on.

The height of railway-station platforms is a question on which much difference of opinion exists. Some engineers and traffic managers—and notably almost all foreign engineers—adopt a low platform about 1 foot or less in height, which renders it necessary that all passengers in entering or alighting from the carriages should use the steps on the carriages; others adopt a platform of upwards of 3 feet 3 inches in height, which allows a passenger to step on a level from the platform to the floor of the carriages. The advantage of low platforms is that they are convenient when passengers or porters cross the line on the level, as in that case they can get on to the platform at any point, whereas high platforms require steps or inclined planes at particular places to give access to them from the level of the rails, and there is much difficulty in putting these steps or inclines anywhere except at the ends of the platforms, in which positions they are inconveniently far apart. If a subway under, or a bridge over the line be provided for the passengers, the porters in crossing the rails from one platform to the other have still to jump up on to the platforms, and the risk of accident to

them of course increases with the height of the platforms. Further the question of conveying luggage from one side to the other of a station has to be considered, and no doubt, so far as merely crossing the line is concerned, with a barrow full of luggage low platforms are more convenient than high platforms. But it is to be remembered that the luggage has eventually to be placed on the floor of the luggage van, which is upwards of 3 feet from the level of the rails, and with well arranged inclined planes, it is in the long run as economical in labour to wheel the barrow up to the height of the floor of the van as to lift each article of luggage up to that height separately from a barrow on a low platform.

The inconvenience and risk to passengers of all ages of being obliged to step to and from the low platforms by means of the carriage steps, which are often slippery, is a further great disadvantage, and outweighs any gain in convenience to the railway staff. It is, however, necessary that the porters should be able to get readily on and off the platform from rail level, and there is no hardship to passengers if they are required to step a vertical height of 6 inches or 7 inches between the platform and the floor of the carriages. Thus a height of about 2 feet 9 inches (fig. 132)

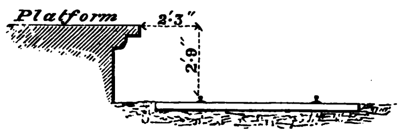


Fig. 132. Height and clearance of platform.

will probably be found the best height for platforms, for both roadside and terminal stations.

If luggage has to be wheeled across the line on the level, easy inclined planes should be provided at each end of all platforms; in all cases sharp drops or steps at the ends of platforms should be avoided, as owing to the necessity of having no standing work within reach of being struck by

a passing train, fences cannot be fixed at the ends of platforms, to prevent persons from falling down them at night. Opposite the inclined planes a level crossing paved with smooth materials, should be laid level with the top of the rails, so as to afford a good pathway for the luggage barrows to be wheeled from one side of the line to the other.

The edge of the platform is generally placed about 2 feet 3 inches from the outer edge of the nearest rail (fig. 132), and this width accommodates all descriptions of rolling stock in general use in England. If the railway be curved, and the outer rail of the curve be elevated above the inner rail, the floor of the carriage will be brought nearer to the edge of the platform on the concave side of the curve, and be thrown further away on the convex side of the curve. This circumstance should be considered where the curves are sharp, as any excess or diminution of the standard distance between the carriage and the edge of the platform is inconvenient, and apt to cause persons to miss their footing.

In some cases the platforms of roadside stations are not placed opposite each other, but so that, assuming the line to run north and south, the north end of one platform may be opposite to the south end of the other platform, as shown in

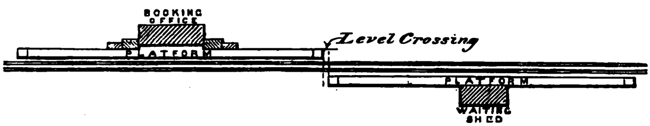


Fig. 133. Block plan of roadside station.

fig. 133. This arrangement has the advantage that passengers have no inducement to cross the line except at the authorised crossing at the end of the platform, but it has the disadvantage of preventing as much concentration of the work of the station under the eye of a station-master as is possible where the two platforms are opposite one another. Where properly arranged footway bridges or subways are

made, there seems to be little advantage in not having the platforms opposite to each other. All new stations are required by the Board of Trade to have bridges over, or subways beneath, the railway for foot passengers, and, with very few exceptions, one or other should be provided at all stations.

Subways under the line are better than bridges over the line, in that they do not interfere with the view of the line from the engine. Further, a subway under the railway for foot passengers need not have more than 6 feet 6 inches headway, which, with the height of the platforms, say 2 feet 9 inches, makes a vertical distance from platform level of 9 feet 3 inches; whereas, a bridge over the railway must be at least 14 feet above the rails, or 11 feet 3 inches above the platform. Thus the subway saves 2 feet in vertical distance travelled by all persons crossing the railway, assuming that the same height would be required for girders to carry the railway in one case, and the footway in the other case. A subway need not be other than well lighted, as skylights can be placed either between the rails or in the six-foot space.

The supports of the roof of a platform must not, by the regulations of the Board of Trade, be nearer to the edge of the platform than 6 feet (fig. 134), and even a greater distance is no doubt desirable. The roof must of course be outside the line of minimum structure adopted on the railway (see page 10); for roadside stations, a low roof is, as a protection against weather, better than a high one. The rain water falling on the roof should be carried by gutters away from the edge of the roof next to the railway; and a convenient plan is to make the supports of hollow cast iron

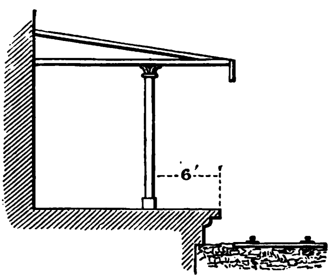


Fig. 134. Roadside station roof.

pillars, which can be utilized as down pipes to convey the water to drains beneath the platform. A sufficient amount of glass should be used in the roof, to afford plenty of light on the platform when a train is standing in the station, at which time, especially if the roof be a low one, a great portion of the side light, is obstructed.

At roadside stations of an unimportant character the booking offices are often placed on the side of the line most convenient to the village or town accommodated by the station, and there are no offices on the other side. A waiting shed should in all cases be provided on both sides of the line, the covering of which should be carried to the edge of the platform. The length of covered platform varies with the importance of each station, and in many cases the platforms are covered for nearly their whole length.

The booking-offices and waiting-rooms should be, if possible, on the same level as that of the platforms, and of the road leading to the station; but this cannot be easily done in the case of stations in cuttings or on embankments or viaducts. In choosing the site for a station this matter is of much importance, especially where any large number of passengers with luggage have to be accommodated. In metropolitan stations of an underground line the difference of level between platforms and the street causes so much difficulty in dealing with luggage, that practically no one with luggage uses an underground line. Much may be done, so far as the passengers themselves are concerned, to mitigate the evil by providing ample staircases, or where practicable inclined planes, so arranged that in-coming and out-going passengers are not intermixed ; but however perfectly the stairs or inclined planes may be arranged, they are a serious inconvenience. If the booking-offices cannot be on the level of the platforms, waiting-rooms or sheds may be, and often are, provided on the platforms, in which position they are a great comfort. Passengers do not like waiting when once a train is due, except in waiting-rooms or

waiting sheds, on the platform. The want of waiting rooms on the platforms is in winter much felt on the Metropolitan lines.

The accommodation provided in station buildings, differs of course infinitely, and has reference to the traffic to be accommodated, and to the financial position of the different companies. The following are almost invariably provided at the smallest roadside stations :—A booking-office for the public ; a booking clerk's or station-master's office communicating with the booking-office ; a ladies' waiting-room, and W. C.; a store room; gentleman's W. C. and urinal; a waiting-shed on both sides of the line.

At more important stations, there are waiting-rooms for 1st, 2nd, and 3rd classes, with separate ladies' rooms, separate offices for the station-master and the telegraph clerks, rooms for left luggage, a lamp-room, a place for heating water for foot-warmers, up and down parcels offices, refreshment-rooms, with kitchen, scullery, and accommodation for the attendants of the refreshment-room ; and ample W. C. and urinal accommodation. A great boon to travellers at important stations is a lavatory, where for a moderate charge they can wash and dress after a journey. This accommodation is now provided at several large terminal stations, and it is to be wished that the provision were extended.

A house, or, in the case of large stations, two houses, should be provided above the station buildings, in which the station-master, and the official next in command, should live. The house ought not to communicate directly with the booking-offices, as too much facility of passing from one to the other is apt to lead to inattention to duty. It is a good investment, in a money point of view, but far more in other ways, for a railway company to provide houses for its station-masters, porters, platelayers, and signalmen. A company in good credit ought to be able to build houses more cheaply than other people, and can afford to let them

to its servants at a lower rent than people who build houses merely for profit ; and it is much to the advantage of the company to keep their men together, giving them an interest in the company, both while at work and when off duty.

The signalman in charge of the traffic should be placed so that he can be easily approached or spoken to by the station-master, or other authorised persons ; but it should be rendered difficult for anyone to go into the signal cabin, except in open view; and the cabin should be glazed all round, so that not only can the signalman see outwards, but the station-master can see inwards, and detect any gossiping or idling. The placing of the cabin is a matter of importance, as on its position much depends in the everyday work of a station.

Roadside Goods Stations.

The goods station and goods sidings are, in the case of most roadside stations, placed under the control of the same station-master as the passenger department, and they should be so situated as to be well under his eye from the passenger platform and from his house. In the case of important roadside stations the goods department is occasionally separated from the passenger department, and placed under a goods superintendent, but generally speaking, one man is responsible for the whole of the work of a station.

The arrangements and requirements of a roadside goods station are much the same as those of a terminal goods station, which will be referred to in greater detail further on. The size and fittings of roadside goods stations vary of course with the amount of traffic to be accommodated. As a general rule there ought to be shed room proportioned to the goods traffic of the station in question, so that there should not be any necessity for unloading perishable goods in the open air. A roadside goods shed of the simplest construction will accommodate two trucks at one time, and the sides of the sheds may be made to open so that carts can

back in to the loading platform ; or if this be inconvenient, the carts may enter at the ends of the shed. A small crane worked by hand, a weighing machine alongside the crane for the articles lifted by it, a weighbridge to weigh a loaded truck, a lock-up store, a small glazed office for the book-keeping of the goods department, a supply of water, and means of lighting by night, form the necessary part of a small goods station. The doors of goods sheds should generally be made to slide and not be hung on hinges, as a large hinged door opening outwards is difficult to manage in a wind, and if it open inwards it cannot be opened or shut if the line in the shed be occupied by trucks or carts. The height of a goods platform should be about 3 feet 6 inches above the rails, and the roadway for carts alongside the platform should be at the level of the rails. All cranes should have jibs long enough to swing from the truck to the carts on the other side of the platform.

A great point to be aimed at in placing the goods sheds is that they shall be easily accessible for carts from the public roads, and that the railway trucks can be taken to and from the sheds to be loaded or unloaded without impeding the work of the main lines. Wherever the levels of the ground permit, simple coal-drops should be provided, which admit of a railway coal-waggon being placed over a void between the rails, so that on discharging the waggon the coal will drop through between the rails into carts below, as shown in fig. 135.

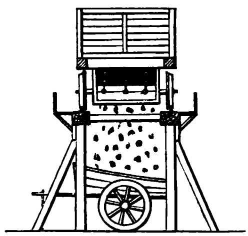


Fig. 135. Coal drop at country stations.

Terminal Passenger Stations.

The mode of arranging terminal stations must have reference not only to the traffic, but also to the ground available

and to the value of the site. Few general rules can therefore be laid down as to the general arrangement or block plans of terminal stations, in designing which the engineer is generally much restricted (especially in London), by the consideration of the cost of the land.

For these reasons, in considering the principles on which terminal stations are planned, it seems best to endeavour to keep in view what has been done by the great companies having their termini in London, rather than what might be done; bearing in mind that in the later built stations the cost of land has in most cases been more restrictive on the accommodation provided, than it was when the older termini were built, and when Paddington, Euston Square, and King's Cross were considered as almost suburban districts.

There are well known examples of three principles of arrangement in the following stations in London:

Great Western, Paddington.
London and North Western, Euston.
South Eastern, Cannon Street.

At the first mentioned, viz. the Great Western Station (fig. 136) at Paddington, the booking-offices are placed

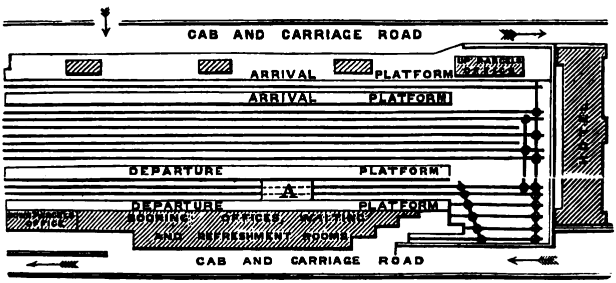


Fig. 136. Plan of Paddington Terminus.

by the side of the main departure platform. A piece of cross platform (marked A in fig. 136, and shown in detail in fig. 137), supported on a dwarf truck, is provided, which

when required is drawn out by hydraulic machinery from beneath the main departure platform, and rises to the same level as the main platforms, becoming a bridge across the rails, and giving access to the second departure platform. The upper sketch in fig. 137 represents the platform drawn out on

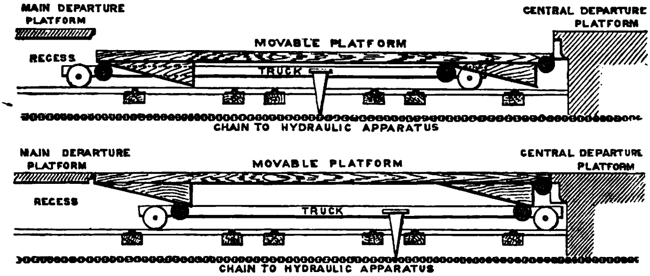


Fig. 137. Movable platf rm at Paddington.

its truck from the recess by means of a chain connected to an hydraulic apparatus, and the lower sketch shows it raised to the level of the platforms on each side. The raising is effected by continuing to haul on the chain after the truck has come out of the recess, which causes the two rollers (shaded in the sketches) to travel along the lower surfaces of the inclined planes fixed below the platform. Small rollers at the end of the platform relieve the friction between the movable platform, and the side of the central platform. By the use of this movable platform three long trains can be loaded at once, if the two trains nearest the booking offices be temporarily cut in halves. When it is necessary to despatch these trains, the movable cross platform is run back to its position beneath the main platform, the first half of the train is backed and coupled up to the second half. Trains of shorter length can be loaded and despatched, when the movable platform is raised.

The position of the booking-offices, near the centre of *the departure platform*, is no doubt convenient, as passengers

approach the train near its centre ; and though there is some inconvenience in the use of a movable platform, the arrangement answers well for a terminal station like Paddington, where trains are not very frequent, while the central position of the booking offices is certainly advantageous where the amount of passengers' luggage is large.

The arrangement of Euston Square Station, shown on fig. 138, affords ready access from the booking-offices to two departure platforms near the centre of the trains which are being loaded; but there is a want of concentration of work in such an arrangement, and a larger staff must be required to work it efficiently than either of the two other

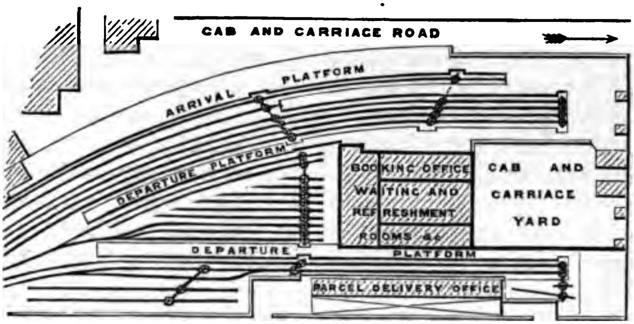


Fig. 138. Plan of Euston Square Terminus.

plans. If this be no objection, the plan has undoubted advantages ; but the working of the station is not so free and unrestrained under this plan as when the booking-offices are placed at the end of the platforms, in which case any platform can be used at pleasure either for arrival or departure.

Cannon Street Station (fig. 139) is an example of this third arrangement of having the booking-offices at the end of the platform. In this plan there is a wide space, or end platform, adjoining the booking-offices, on which are placed the luggage-office, book-stall, gentlemen's W. C. and

urinals, and the refreshment department. A space of 40 or 50 feet lengthways of the station is required for the end

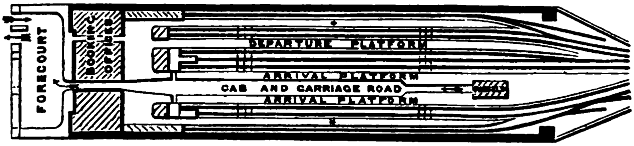


Fig. 139. Plan of Cannon Street Terminus.

platform in order to give plenty of room to move about, as the arrangement of all the platforms being approached from the end platform entails a concentration of work near the booking-offices. Ample means of ingress and egress should be provided through the booking-offices on both sides and in the centre of the end platform. The disadvantage of having the offices at the end of the station, is that passengers have to walk, and luggage has to be wheeled, a longer distance than in either of the other two arrangements. The advantages are, that any number of the platforms can be used for despatching trains at the same time, and similarly all the platforms can be used at other times for the reception of arriving trains. The facility of using platforms for both purposes is extremely useful where a large suburban traffic has to be accommodated, the tide of which is strongly incoming in the morning, and strongly outgoing in the evening. There is also no difficulty with this arrangement of a station in using a train, which has just arrived and discharged its passengers, immediately afterwards as a departure train, to start again in the opposite direction with a fresh load from the same platform. Further, the work is more concentrated under the eye of the superintendent than is the case by either of the former plans, and what is of much consequence, the arrangement under consideration more completely utilises a limited quantity of land. It is undoubtedly economical in space to have a line of rails on each side of platforms, and a

platform which is wide enough for one train, is, with a comparatively trifling addition, wide enough for a train on each side of it, especially if luggage be not deposited on the platform, but only wheeled along it from the place where it is labelled to the luggage-van in the train.

The public may, when the booking-offices are at the end of the station, be admitted without inconvenience to the end platform, but it is seldom necessary for any but passengers and porters to be on the loading or unloading platforms. This circumstance alone is of much consequence in crowded London stations, as the arrangement under consideration enables the Company, by placing gates across the ends of the longitudinal platforms, to prevent a crowd of friends coming to see people off in the train, or to receive them on their arrival, which, except in the case of ladies or invalids, is usually unnecessary, and is oftentimes disagreeable to all parties. The porters in charge of the gate, or the platform superintendent, ought, however, to have discretionary power to permit, in exceptional cases, friends of ladies or invalids to pass the barrier. The exclusion of non-travellers from the platform can scarcely be carried out on either of the two plans first referred to, except by overcrowding the booking-office, as no distinction can be made between travellers and non-travellers until the tickets have been taken.

Taking into consideration the double use of platforms, the concentration of traffic under the eye of the superintendent of the station, the facility of managing and controlling the passengers, as against the inconvenience of passengers and luggage having to pass over a greater length of platform, the balance of advantages seems to be in favour of the third description of arrangement, in cases where the number of trains to be accommodated is large and their character various.

Every line in a station used for trains, including those used *for empty* carriages should have its separate signal,

and this necessity entails the use of a large number of signals in the case of stations with many platforms. The signals are usually semaphore arms arranged one above another on posts on the signal-box, or occasionally there is a separate signal-post at the end of each platform. There should also be signals for shunting empty trains and engines and all these signals should be interlocked one with the other. In some cases in order to avoid the exhibition at all times of a large number of semaphore arms or lamps, the signals for different platforms are given by discs which have on them numbers which can be well seen by day and which are illuminated at night. In this arrangement only one signal need be exhibited at one time, and the drivers of trains have only to consider the disc with the particular number on it which refers to the platform which they are intending to leave or to approach.

As a general rule, it may be laid down that in terminal stations the lines of rails in the station-yard should be so laid out that the lines alongside the platforms can be used indifferently, either for the arrival or departure of trains, and that consequently every platform line should be joined directly or by cross-over roads and without back shunting to both the main up and down lines. There should thus be an 'out' and an 'in' signal for every line alongside a platform, and these should be all interlocked with the points, so that trains can arrive at or depart from any platform under the protection of the ordinary standard signals, and without the necessity of hand-signals. It is often found that at times of pressure, such as during races, reviews, or at holiday time it is of the greatest convenience to be able to use every platform at will, either for departure or for arrival, and it is just at such times that the chance of an accident from hand-signalling is greatest. If some of the platforms are rigidly set apart for arrival, and others for departure, and the interlocking signals are arranged so that a train cannot be signalled to leave an arrival platform, and *vice*

versâ, the adaptability of the station to times of extraordinary traffic, is seriously diminished, and the risk of accidents with improvised arrangements is proportionately increased.

In all the three arrangements of terminal stations shown above, a roadway alongside the chief arrival platform is provided for cabs and carriages, to which empty cabs and carriages have access at the end of the roadway furthest from the exit from the station, so as to avoid the necessity of empty cabs entering the station by the same way as the loaded cabs leave it. The cab roadway may be easily placed between two arrival platforms, so as to accommodate the passengers from two trains. A roadway of from 20 to 25 feet in width is sufficient to give room for two lines of cabs and for a single stream of traffic between the two rows, but it is better if possible to give a width of from 30 to 35 feet, which allows of two rows of standing cabs and of two streams of traffic. The best material for paving the cab road is wood laid on planks resting on a good bed of concrete. The level of the roadway should be about 6 inches below the level of the platforms.

The minimum width to be given to platforms of terminal stations admits of much difference of opinion. Perhaps the best mode of treating the question here is to give the sizes of the platforms at Cannon Street Station, where land was extremely expensive, and where every dimension was carefully apportioned, but where a large metropolitan and suburban traffic is accommodated, in addition to country and continental traffic. The platform area at this station is probably minimised, but the station accommodates efficiently a very large mixed traffic of long and short journey trains, amounting at times to as many as 400 trains in and 400 trains out in a working day. The table on the next page shows the length and width of the different platforms. If more room could have been spared, the eastern and western platforms would have had 4 or 5 feet added to their width.

Cannon Street Station.	Length	Width
	Feet	Feet
Eastern platform for local and suburban traffic (a line of rails on each side of platform)	522	$13\frac{1}{2}$
General departure platform for main line traffic (a line of rails on each side of platform)	665	19
General arrival platform for main line traffic (a line of rails on one side only)	721	12 opposite cab road 30 beyond cab road
Western platform for local and suburban traffic (a line of rails on each side of platform)	486	$13\frac{1}{2}$
Cab road between two arrival platforms	400	22

The material with which platforms are paved must be determined with reference to the amount of traffic which may be expected on them, and the degree of exposure to which the platform will be subjected. It should be of such a character as will afford a smooth and durable surface for the wheels of the luggage trollies, but it must not be slippery either when wet or dry, and must resist the action of the sun, rain and frost. Wooden platforms are extensively used in stations completely covered, such as Victoria Station, and the stations on the Metropolitan and District Railways. Such platforms are comfortable for persons waiting at the station, and they have the advantage of being easily repaired, while their first cost is not great. They are, however, not very durable, are apt to wear unevenly, and are difficult to keep clean. Probably the most satisfactory paving for platforms of stations with a heavy traffic is Yorkshire stone in large landings, which is durable, cleanly, and smooth without being slippery. Asphalte, even of the best quality, is not equal to stone, as it is apt to become too smooth and slippery, though it has some advantage in point of cleanliness. Paving of bricks or tiles is sometimes employed, and forms in many respects a comfortable platform ; but

the number of joints is a great disadvantage, and it is difficult to get any large quantity of bricks or tiles which will wear uniformly. At country or suburban stations some descriptions of tar pavement, formed of gravel, broken stones, or hard burnt clay mixed with coal tar, and rolled till a complete union takes place, are used. This sort of platform is cheap and tolerably satisfactory; but unless great care is taken in laying it down, tar pavement will give way under a hot sun, and will stick to the feet of passengers, or be cut up by the wheels of luggage trollies. At stations where there is little traffic, the platforms are often formed of gravel well drained, rolled, and consolidated, and with an edging next to the train of Yorkshire stone or of blue Staffordshire coping bricks.

The edge of the platform should be made to overhang the vertical wall or other support which is next to the train, as shown in fig. 140, so that any one who may accidentally fall on the line when a train is coming up to the platform may have room to lie beneath the edge of the platform, out of reach of being struck by the steps of carriages. In the case of wooden or paved platforms this may readily be done, and with a little ingenuity it may be carried out with all descriptions of platforms.

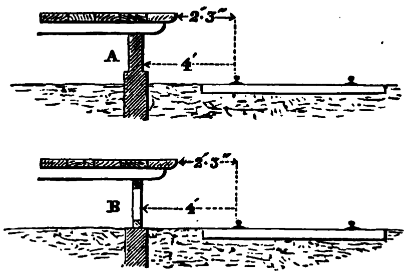


Fig. 140. Overhang of platforms.

The space beneath platforms may be filled up with earth, but in the case of paved or wooden platforms it is better left void. In the latter case dwarf brick walls (shown at A on fig. 140) will serve to carry either paving or wooden flooring. Wooden supports (shown at B on fig. 140), are

often used to carry the timbers of the flooring, but walls will as a rule be found more advantageous, being cheaper to maintain, and safer from fire. Wherever wooden platforms are used, good ventilation should be given to all parts of the timber to avoid dry rot. The planks of wooden platforms are often laid with a small space between the planks, which is convenient for drying the platforms when they are exposed to wet weather, and saves a little planking. On the other hand, the gaps between the planks cause disagreeable draughts if the space beneath them is, as it should be, freely ventilated, and small articles such as money, keys, or papers, can drop through the gaps, causing much trouble. These matters appear trivial objections; but when one has to deal with the enormous number of people who use railway stations, the trifles affecting perhaps but one man in a thousand have to be considered, and little defects are found to be of importance.

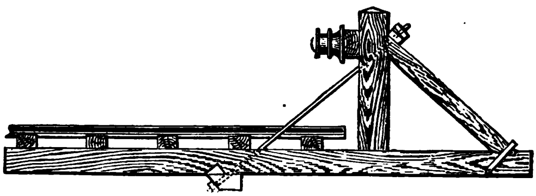


Fig. 141. Buffer stops.

In terminal stations some means are required for arresting the motion of a train which is being shunted back into the station, or of one that comes in at slightly too great a speed. These barriers are called buffer stops, and in fig. 141 is shown a simple and effective arrangement. It will be seen that two longitudinal timbers rest beneath the sleepers, and that the weight of an engine or carriage will prevent the strain on the struts and diagonal tie bars from tilting the whole framework backwards. Buffers or springs are placed on the buffer stops, at the standard height of the buffers of carriages. Buffer stops are not made, except in a few

peculiar positions, for the purpose of endeavouring to stop a runaway train, but are intended for any trifling miscalculation of engine-drivers in shunting trains back into the station. In positions where the chance of a runaway train is contemplated, such as in terminal stations, at the bottom of an incline, heaps of earth or rigid obstacles are often placed. The true object, however, that should be aimed at in such cases, is to put something in the path of a train which will gradually arrest its motion, and the attempt should not be made to stop the train with suddenness by any rigid body, and a heap of earth is objectionable on this score. Probably the best stop would be a timber framing of considerable length, which would be gradually destroyed by a runaway train, in the destruction of which the momentum of the train would be at the same time gradually and not suddenly absorbed.

Great attention should be given to stairs leading to platforms, and the following rules should be observed :—

All steps should be protected from the weather. No steps should be higher than $6\frac{1}{4}$ inches in the riser, or narrower than $11\frac{1}{2}$ inches on the tread, but the best step is probably one $12\frac{1}{2}$ inches wide, and 6 inches high. An uneven number of steps in each flight is found more convenient than an even number. Landings at least 4 feet wide should be provided

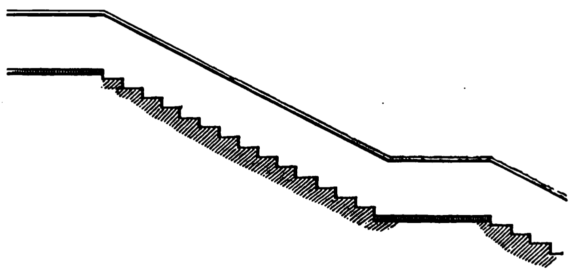


Fig. 142. Steps showing arrangement of landings.

at about every 7 feet 6 inches of vertical height (fig. 142).

so that in case any one falls down stairs, he may be prevented from falling more than that distance. Handrails should be provided on both sides.

The materials of which the steps are formed should be such as to give a good foothold, and should not wear away rapidly or unevenly. On the Metropolitan Railway wooden steps are generally used, covered at their nosings and on part of the treads with chequered brass plates, and these appear to answer well, so long as the chequering is kept sharp. The foothold is, however, mainly dependent on the chequering on the brass, and such steps do not fulfil one great desideratum, viz. that they should look safe as well as be safe. One feels that all depends on the condition of the chequering, which at a glance cannot be investigated. Perhaps the safest stairs are of wood covered with lead, but lead will not long resist heavy traffic. The next in order of merit are probably Hawksley's steps, shown in fig. 143. These are composed of small blocks of wood placed with the grain endways, and with interstices between each block. The best wood for these steps appears to be of three descriptions, viz. oak, which best resists the wear of the traffic, and is placed near the edge of the tread ; pitch pine, which is more absorbent of grit from the boots, and gives a firmer foothold than oak, is placed in the centre of the tread; and deal, which for cheapness, is placed at the back of the tread near the riser, where the wear and tear from traffic is small. The endurance of these steps under heavy traffic is remarkable; the blocks of wood can at any time be replaced at small cost without disturbing the general arrangement of the staircase, and the foothold they afford is very good.

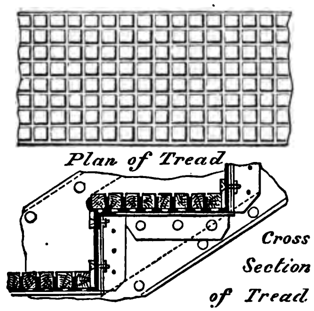


Fig. 143. Hawksley's Steps.

All the platforms, stairs and approaches, should be

well lighted at night with gas, which should be so arranged that it can be turned on to or off any platform without affecting the others. The valves controlling the gas should all be concentrated at one index plate, which may be placed in a locked glazed case, so as to prevent unauthorised interference with the valves, and yet allow the station superintendent to see how the gas is being regulated by the man under whose charge the lighting arrangements are placed.

If possible, there should be no obstructions like lamp posts on the platforms, but it is difficult to avoid the necessity of using them ; for if, as is often the case, platforms are situated at a long distance from the side walls of the stations, brackets to carry the lamps become inconveniently long, and the only alternative is to hang the lamps from the roof, which is attended with many inconveniences. Hanging lamps necessitate the use of universal joints which are constantly under wear and tear, as the lamps are continually swinging in the wind ; the main also has to be carried along the roof, where it is comparatively inaccessible, and where an escape of gas may go on unheeded for a long time ; and in stations with lofty roofs the pendant pipes become extravagantly long.

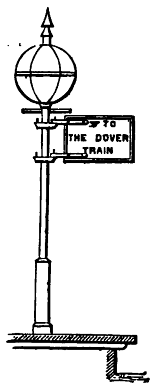


Fig 144. Platform lamp and notice-board.

Lamps should be placed about 30 feet apart, and if lamp posts are used, advantage may be taken of them for the exhibition of notice-boards, placed high enough to allow passengers to pass beneath them (fig. 144). When the notice-board is intended to direct passengers to a particular train, the board is turned athwart the platform, and when not in use it is turned fore and aft of the platform. At spots where tickets are collected or luggage labelled, extra means of lighting are necessary, and a large gas lamp is often used with a shade over it (fig. 145), to *concentrate* the light on the particular spot to be illuminated.

The place for labelling luggage should be near the door

from which passengers enter on the platforms from the booking-offices. One or two weighing machines (fig. 146),

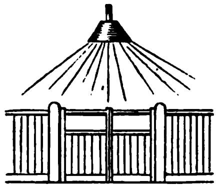


Fig. 145. Lamp at ticket barrier.

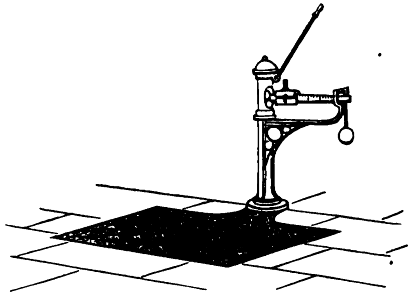


Fig. 146. Luggage weighing machine.

flush with the platforms, and a small office for a booking clerk, and a case for the luggage labels, are required. At important stations from which much luggage is dispatched, a special kind of label case of an ingenious construction (fig. 147) is used, in which each pigeon-hole, with the exception of one (which is hinged) at the end of each row is closed with a sliding door, and thus, as will be seen by the figure, only one pigeon-hole in each row can be opened, and only one description of label can be withdrawn at a time from each row.

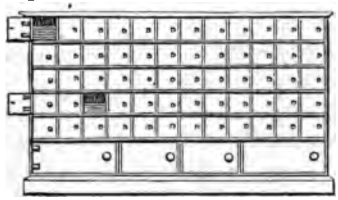


Fig. 147. Luggage label case.

All W. C.s and urinals ought to ventilate directly to the open air, and no brasswork of any description should be placed in them, or it will probably be stolen. The walls of W. C.s should be non-porous and easily cleaned, and the material should be such as cannot be written on; to meet these requirements white glazed tiles or enamelled slate are perhaps the best materials. A convenient size for a W. C.s is 3 ft. wide, and 5 feet long with a door 2 ft. 4 in.

wide. The pan apparatus, and not the valve apparatus, is best fitted for the rough usage of railway stations. To allow of free circulation of air the top of the door should not touch the top of the door frame by about 6 inches. A hat and coat peg in each W. C. is a great convenience. A convenient size for urinals is 27 inches between the slate partitions, which should project from the wall about 2 feet; they require to be supplied copiously with water, both at the front and sides, and care should be taken that the water reaches into all the angles formed by the partitions.

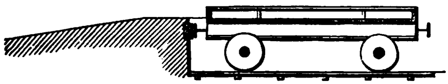


Fig. 148. Carriage dock.

Means are required at most railway stations for loading and unloading horses and roadway carriages, or vans, and the place devoted to this purpose is generally called the carriage dock (fig. 148). For this purpose a platform about 3 ft. 6 in. high is most convenient for horses, and one about 4 feet high is best for carriages. Carriages are loaded endways to the railway truck, and short iron troughs are hinged on the end of the platform, to fall to the railway truck, along which the carriage wheels run when passing over the space between the buffers. The platform on which horses are unloaded is generally paved with wood blocks, if under cover from the weather, and care should be taken to give good foothold for the horses, who are generally nervous and apt to slip when going in and out of the horse-boxes. A gauge (fig. 149) showing the height and width of the minimum structure on the railway should be fixed adjoining the carriage dock, so that all vehicles after they have been loaded on the railway trucks may pass under the gauge.

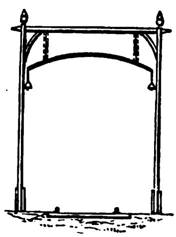


Fig 149. Carriage gauge.

Means are required in all stations for passing railway carriages or trucks from one line to another within the station, and there are generally cross-over roads provided for the purpose between the different lines of rails. In addition to cross-over roads, which often cannot be used in consequence of trains standing foul of them, turntables or traversers are provided in all important stations.

A turntable (fig. 150) is a circular platform on which rails are laid. The platform of the turntable is pivoted in a pit below the rails, and is supported by wheels or rollers

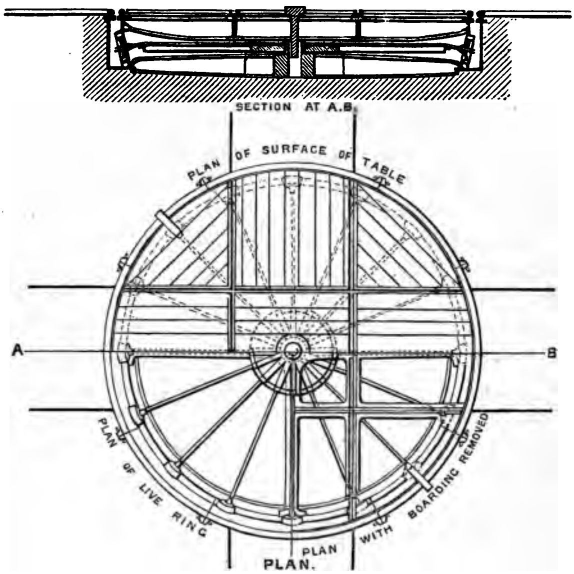


Fig. 150. Carriage turntable.

near its circumference, resting on a circular rail called the roller path. The rollers, which are preferable to wheels fixed to the platforms, are generally placed in a separate framework called a live ring, in order to diminish friction. By means of a lever the weight of the vehicle

can be thrown on the central pivot so as to relieve the pressure on the rollers, and make the revolution of the turntable more easy.

The general use of turntables for moving carriages is being abandoned at the present time in England, for many reasons. The insertion of a turntable in a line of way is an evil in itself, as it implies that the continuity of the rails must be broken, and though means are adopted in all good modern turntables for throwing the revolving apparatus out of gear, so that the frame of the turntable may rest at such times as solidly as possible on the wheels of the live ring, and not on the pivot, yet at best running over a turntable is like running over a bad and ricketty piece of line, and produces wear and tear both in the turntable and in the engines and vehicles.

The carriages also which are now used are so long that the turntables which will accommodate all descriptions of carriages must be upwards of 20 feet in diameter, which is an inconvenient size alongside a platform, as it implies that a large segment must be scooped out of the platform to allow the carriage to revolve, or else that the platform must be depressed for an equal space to near the level of the rails. Further, as the space from centre to centre of two lines of rails is seldom more than from 11 to 12 feet, there is not room for turntables of so large a diameter as 20 feet to be placed opposite one another. Thus, if turntables large enough for modern rolling stock are used, they must be placed diagonally on plan, which is inconvenient, as when in use they foul more length of the line than if a traverser is used.

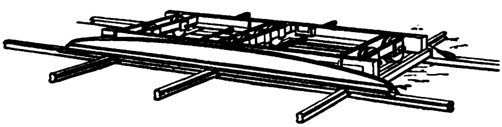


Fig. 151. Carriage traverser.

A traverser (fig. 151) is a low frame or dwarf carriage

about one foot high, mounted on small wheels which run on rails laid at right angles to the direction of the railway, and on each side of the traverser, just above the level of the rails, are attached two rails on to which carriages can be easily pushed. These rails are either made self-adjusting to the extent of one or two inches of level, so that if a carriage be pushed towards the traverser, the flange of the wheel will, by pressure against the end of the traverser rail, depress that end of the traverser rail, and allow the carriage to run up on to the traverser, or else instead of the self-adjusting rails, short inclined planes are used, hinged to the ends of the traverser, up which the carriages are pushed on to the rails of the traverser. When a carriage is on the traverser it can be pushed at right angles across the lines of way to any desired position, and then be pushed off the traverser in the same way in which it was pushed on at starting. When the traverser is not in use it can stand under the platform in a space provided for the purpose, or it can remain in the six foot space until it is again wanted.

When traversers are adopted for use in terminal stations, it is usual to provide at least one turntable for carriage stock, as there are some descriptions of carriages and vans which travel more conveniently, with a particular end first, and consequently require to be turned when their journey is ended, and before they have to travel in the opposite direction.

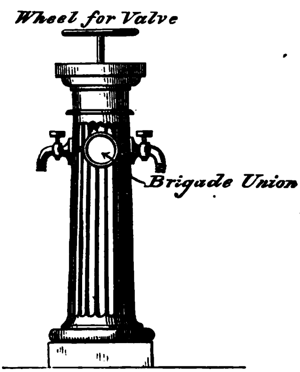


Fig. 152. Hydrant.

In important stations the spaces between the rails and the six foot spaces are often paved with bricks or tiles, in order that the surface may be easily kept clean. Hydrants (fig. 152) are provided in

suitable positions between the rails, for washing the carriages and the platforms. The hydrants should be furnished with screws, to which the standard fire brigade unions ($2\frac{1}{2}$ inches diameter) can be fixed, and the bottoms of the taps, from which pails are filled, should be screwed so that a small hose can be attached to them, for the purpose of washing the carriages, or watering the station, for which purposes the large fire hose is unnecessarily cumbrous.

The arrangements of the fittings of the booking-offices at important stations require much consideration, on account of the great number of different sorts of tickets which are issued. Railway tickets, when ready for issue to the public, are kept in cases of a particular construction, in which every ticket is easily accessible, and in which the unissued tickets are well in view of the head clerk. The tickets, arranged in packs, are placed in square tubes, down which they slide as the lower tickets are in turn removed, and only one ticket, viz., that which is at the bottom of the pack, can be withdrawn at once. The tickets are numbered consecutively upwards, and the head clerk can at any time take stock of the tickets issued, and check each booking clerk's accounts. The booking-windows, at which the public take their tickets, should be placed so that the different streams of passengers do not intermingle, and tables should be provided outside of the windows (fig. 153), on which a passenger can place his small impedimenta while he is taking his ticket. These tables are generally so placed as to act also as barriers, and prevent crushing at the ticket window. The sills of the ticket windows are usually about 4 ft. 3 in. from the ground.

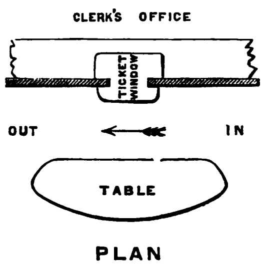


Fig. 153. Ticket window.

The fittings of the parcels office, cloak room and waiting rooms, require no special notice. The room or rooms for

the accommodation of porters should be well lighted and should have a fireplace, at which small articles of food may be warmed. W.C.s, urinals, and lavatories, should be provided for the use of the porters, apart from the passengers' accommodation. A guards' room is required at terminal stations, with lockers for their clothes, flags, lamps, &c.

The lamp room requires special fittings, such as a counter covered with lead, racks in which lamps can be placed, places for storing oil, cottons, lamp-glasses, and other stores. The counter on which the lamps are trimmed should be in the form of a shallow tray, with a fall towards drain pipes, which will carry off to a storage receptacle any oil which may be spilled in trimming the lamps. The door of the lamp room should be wide enough to admit the barrows by which the lamps are taken to and from the trains.

A boiler, heated by a small furnace, and a small room, are required for heating and filling footwarmers. The spare heat from the furnace may be used for heating a closet, in which footwarmers when filled may be kept hot. If foot-warmers are made without any covering of carpet, they may be plunged into a boiler, and the stoppers being removed, the water may be boiled, and be kept boiling in each foot-warmer separately.

At the most important stations the wheels and other parts of carriages are examined, and the wheels oiled or greased. Accommodation is wanted therefore for the men charged with this duty, including a store for oil, grease, spare bolts, window straps, cushions, hinges, glass for windows, and other articles likely to be wanted for small repairs.

Terminal Goods Stations.

The arrangement of an important goods station is a matter requiring the greatest care and experience, as any error of arrangement, either of plan, or in the description, or

position of the plant (such as cranes, weighing machines, or turntables), is of serious importance, from the continual use to which all parts of a busy goods station are put. When it is considered that it is no uncommon thing for 1,000 trucks of goods, exclusive of minerals, comprising perhaps from 3,000 or 4,000 tons of merchandise, to be dealt with in every twenty-four hours at some of the leading stations, it is obvious that convenience of arrangement and facility of handling this large quantity of goods are of immense importance.

In the general arrangement or plan of a goods station, there are two leading principles to be kept in view: (1) that the utmost facility must be given for working the goods trains, (2) that this must be done while at the same time the best means of ingress and egress are secured for the roadway vans by which the goods are brought to or taken from the station. The management of goods traffic is essentially different from that of passenger traffic in this respect, that while passenger traffic is continually arriving and departing during the business hours of the day, goods traffic is frequently almost entirely in one direction at one particular time of the day, and in the other direction at another time. Goods are collected from the consignors and delivered to the consignees during the working day, and thus the busy times at the goods stations are the night hours, during which the bulk of the contents of the trains are loaded and unloaded. The departing goods trains from London (outwards goods) are loaded in the afternoon and the early part of the night, and by midnight the trains are generally on their journey into the country.

On the other hand the arriving goods trains (inwards goods), which have been loaded in the country during the day, begin to arrive about midnight, and from midnight to about noon these trains are being unloaded and their contents dispatched by vans to their destination. Thus a *terminal goods* shed is often used exclusively for outwards

goods at one time, and for inwards goods at another. On some railways different sheds are appropriated to outwards and inwards goods.

The practice of the great railway companies differs considerably in the mode of working their goods stations. Some companies arrange in the goods shed a complete train, or perhaps, if there are platforms enough, one or two trains are loaded at the same time, with the trucks arranged in their proper order to be dropped at the different stations on the line, and in that case the porters load those trains before they begin loading any trucks for stations not accommodated by the trains in question. Other companies load the trucks indiscriminately in the goods shed (as the road vans bringing goods arrive) and make up or marshal the goods trains in their proper order afterwards either in the goods yard outside the shed, or, when ground is scarce, at sorting sidings perhaps a mile or two distant. When there are proper arrangements for marshalling the trains, the latter seems the better plan, as the object of the manager of a goods shed should be to get the road vans unloaded, and the trucks loaded as quickly as possible, so clearing his shed continually of the incoming vans,

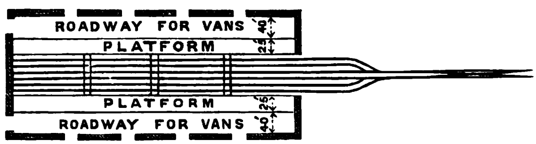


Fig. 154. Goods shed with end exit for trains.

the arrival of which must of necessity be somewhat irregular in point of time. The arrangement of a goods shed depends very much on which of these plans of working is to be adopted. If the former plan of loading complete trains is preferred, the goods station need only have exits for the trucks at the end, as shown in fig. 154, but if the latter plan of loading the individual trucks is adopted, the shed should be so arranged that each truck may easily be removed separately from

the shed, and an empty truck brought in its place. Thus to carry out the second arrangement of working numerous lateral exits are required, and there may be in addition the end exits necessary under the other plan. The lateral exits can be provided by openings at the sides of the shed, as shown in fig. 155, and by having numerous turntables or traversers on the line in the shed, on which the trucks stand

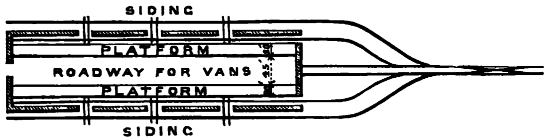


Fig. 155. Goods shed with lateral exits for trucks.

while they are being loaded, communicating with parallel sidings outside the shed. By this arrangement any truck can be run on to a turntable or traverser, which may be worked by hydraulic machinery, and so be removed to a siding outside the shed, to wait until there are sufficient trucks ready to be taken to the sorting sidings.

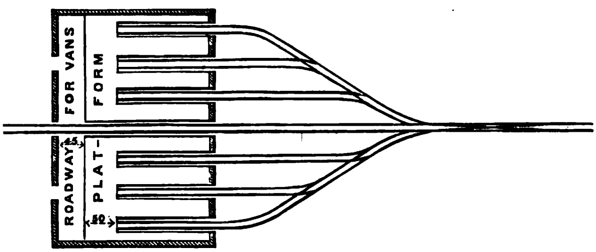


Fig. 156. Goods sheds with end exits.

A plan for a goods station to carry out the system of separate and independent loading is that shown in fig. 156, which has been carried out at an important goods depôt. The arrangement in this case is to run a number of short lines into the shed transversely to the length of the shed, and to load the trucks at short platforms communicating with a

wide end platform, at which the roadway vans are loaded and unloaded, and extending longitudinally for the whole length of the shed. This plan has the disadvantage of necessitating the trollying of all goods from the van to the truck, but in other respects it is very convenient.

An usual plan of a goods station is to have a line of rails on each side of the station, with a platform alongside it, and a roadway for vans in the middle between the platforms, as shown above (fig. 155). The roadway should be wide enough to accommodate a row of vans standing endways to the platform at each side, and to leave ample room for vans to draw out from or back into the platform at the same time. The management of the vans and their drivers is a most important and troublesome part of the conduct of a goods station, while the marshalling of the railway trucks is comparatively easy. A van standing end on to the platform with the pole removed will occupy about 12 feet, and the space provided for the van to draw away when it has been emptied or loaded as the case may be, should be at least 20 feet more. Thus the central roadway should have a width of about 45 feet.

A similar arrangement, so far as longitudinal platforms are concerned, is that shown in fig. 154, but the lines of rails are in this instance placed in the centre of the station, and the roadway vans load and unload at the sides of the shed. Some of the lines in the centre of the station may in this plan be conveniently used for sidings, communicating with the loading lines by means of traversers, so that a shed on this plan can be used either for loading complete trains or separate trucks. The space between the rails of all lines in a goods shed should be paved level with the top of the rails so that horses and vans can pass over them in any direction.

The goods platform should be from 20 to 30 feet wide, according to the nature of the traffic, and to the question whether much or little room for storage is required. The

height of the platform should be about 3 ft. 6 in. from the rails, and the roadway should be level with the rails.

In the arrangements shown in figs. 154 and 155 there should be a crane for every truck, and it should be so placed that its jib will swing easily over the truck, and to the fore-end of a van when placed end on to the platform; or, if the platform be very wide, there should be two cranes and the circles described by the ends of their jibs should intersect so that one crane can pick up goods put down by the other crane. At the present day cranes worked by hand are almost things of the past; and in important terminal goods sheds, hydraulic cranes are usually adopted. Hydraulic cranes for goods sheds (fig. 157) are made to lift from $1\frac{1}{2}$ to 2 tons; they work with great rapidity and ease, and are perfectly under the control of one man.

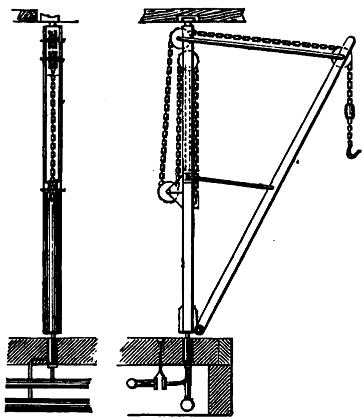


Fig. 157. Hydraulic crane.

The sidings of a goods yard should communicate one with another, by shunting through points and crossings, and turntables and traversers ought to be used as little as possible in a goods yard as a means for moving trucks from one line to another. In goods sheds and in exceptionally crowded places in the yard turntables cannot be avoided, but they are wasteful in the time and the labour required to work them.

Hydraulic capstans (fig. 158) are extensively used in goods stations and yards for shunting trucks or working *turntables* and traversers. These capstans are vertical re-

volving drums, made like the bollards usually fixed by the side of docks and quays, to which ropes are made fast. A small hydraulic engine below the rails, which can be started and stopped by placing the foot on a treadle, causes the capstan to revolve, and by means of a rope attached to

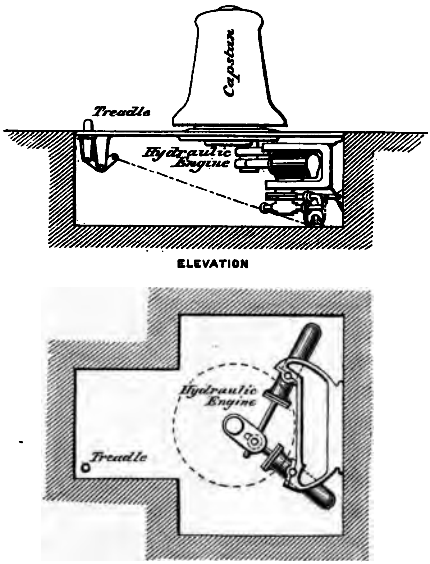


Fig. 158. Hydraulic capstan.

the trucks and wound two or three times round the capstan many manœuvres can be rapidly and cheaply performed.

Weighbridges (fig. 159), for weighing from 15 to 20 tons, are fixed in sidings leading from the main line into the goods yard, and in other suitable positions, for weighing loaded trucks; but they should not be placed in lines necessarily used by the engines, the weight of which is too great to be conveniently passed over the weighbridge. The steelyard and index of the weighbridge are generally placed inside a ...e alongside the weighbridge.

In addition to the weighbridges small weighing machines (similar to those shown in fig. 146, p. 204) for weighing from one to two tons should be fixed within the swing of each crane in the goods shed, as each article requires to be separately weighed before it is loaded. A small desk for

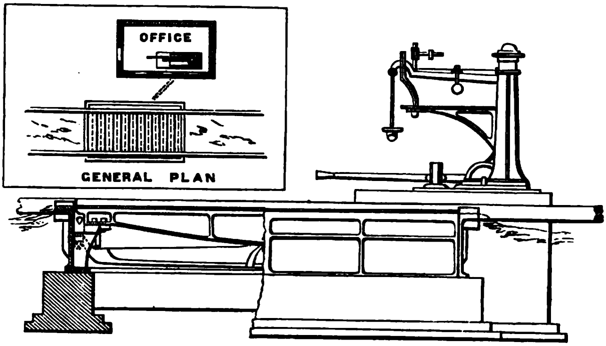


Fig. 159. Weighbridge.

booking the weights is placed near the weighing machines, and is generally portable, so that it can be moved to the most convenient situation for the different descriptions of goods which may require to be weighed.

Light and good ventilation are very necessary for goods sheds in which so much hard work is performed, and these matters have to be carefully considered in judging of the expediency of placing a store over a goods shed. In many cases a store so placed, and accessible by hydraulic lifts, is of great use, as it is impossible to carry on a great goods traffic without having a certain quantity of merchandise which cannot be at once removed, but requires storage. Such merchandise cannot be allowed to remain long on the platforms, as it would interfere with the regular work of the shed; and if, as soon as it is unloaded from the trucks, it can be placed at once on a lift, and sent to a store above the shed

instead of being sent in a truck to a storehouse at some other part of the goods depôt, the result no doubt is economy and convenience so far as those particular articles are concerned. The storage of goods is, however, exceptional, and the working capabilities of the goods shed ought not to be sacrificed to storage facilities. It is possible, by placing a store only partly over a goods shed, to give facilities for storage without too much sacrifice of the light and ventilation.

So much of the work of a goods shed is done by night that the provision of artificial light requires much consideration, particularly with respect to the risk of fire. The lights should be either concentrated in the roof or placed round or near to the pillars of the cranes, where they will not be exposed to the risk of being struck by bales of goods. In many cases the gas jets are protected by wire screens, but these impede much of the light, and attention should rather be given to putting the lights in safe positions than to protecting them by artificial means.

A good supply of water, both for cleansing purposes and as a provision against risk of fire, is indispensable at all goods depôts. There should be numerous hydrants, with unions of the proper brigade patterns for fire hose and also unions for smaller hose for washing and watering the platforms, roadways, and other places, as described above for passenger stations.

Cattle pens are required at many stations. These are generally placed on a separate platform, alongside a siding, apart from the rest of the yard, and are made of stout posts and rail fencing about 5 feet high. Each pen is generally about 18 feet square, and the gates should open outwards. There should be ample space between the edge of the cattle platform and the side of the pens for cattle to pass along the platform to and from the trucks, as it is often impossible to arrange the cattle in the pens in the exact order in which they are to be taken away. Both the pens and the platform should be well paved with stone sets. Each pen should

be furnished with slate or iron troughs, supplied with plenty of good water for watering the cattle, and there should also be a manger for hay. A good supply of water, with hydrants and hose, is required for thoroughly cleansing the cattle pens and cattle platforms.

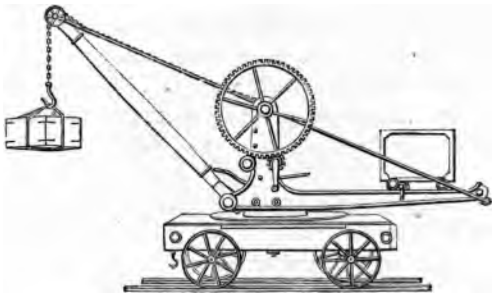


Fig. 160. Movable hand crane.

In most goods depôts special cranes are provided for lifting weights, up to 10 or 12 tons. These cranes (of which an example is shown in fig. 160) are often mounted on trucks running on rails, so that they can be moved to

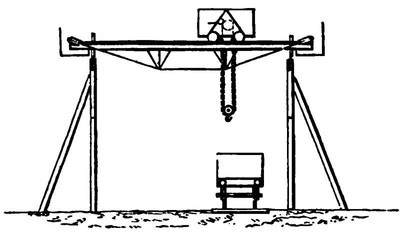


Fig. 161. Traveller.

convenient situations as required, and they are occasionally worked by steam or hydraulic power. At stations where there is much stone loaded and unloaded, travellers (shown in fig. 161) with crabs working overhead, and capable of movement

in any direction, are used. These should be worked by steam if there is much stone to be dealt with.

Coal drops (fig. 162) are required at many of the principal urban stations, so constructed that the railway waggon containing the coal may be placed over a shoot which will discharge the coal into sacks below the drop, where it can be conveniently weighed, put into roadway waggons, or otherwise dealt with. It is of much consequence that the railway trucks may be easily and rapidly taken from the coal drops, and for this purpose there are many ingenious

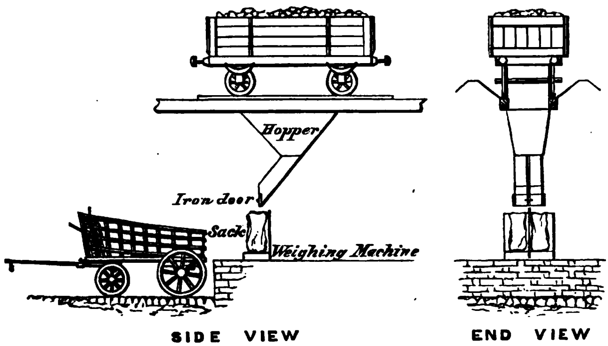


Fig. 162. Town coal drops.

arrangements, comprising hydraulic lifts, hydraulic capstans, or inclines, for working the trucks to and from the sidings according to the special arrangements of different stations.

An important but unpleasant traffic is that in manure, which is being constantly taken from towns into the country. If possible there should be sidings specially devoted to this traffic, which should be kept apart in an enclosed part of the goods depôt, or in a detached yard.

A great deal of goods traffic, particularly in the case of furniture, vegetables and fruit, and dead meat, is now carried on in roadway vans or waggons, which are placed loaded on railway trucks and taken to their destination without break-

ing bulk. To accommodate this sort of traffic, loading banks approached by an easy incline are required, similar to the carriage docks described for the passenger stations, but on a larger scale. These loading banks should be so arranged that there should be a wide flat platform adjoining the railway trucks, on which the horses may be conveniently put to and taken out of the roadway waggons.

The arrangements for working mineral traffic, including the loading and shipment of minerals, and the intricate subject of marshalling and sorting trains are subjects of extreme importance, and have been most carefully and successfully worked out in many places. These matters appertain however more to the subject of engineering construction than to that of Railway Appliances, and even if they came legitimately within the scope of this work it would be impossible to consider them properly within the space available in this volume.

Locomotive Depôts.

At important roadside and terminal stations accommodation is required for locomotives; and a turntable, from 40 to 45 feet diameter, for turning the engines, is necessary. An engine turntable (fig. 163) consists of two girders (generally of wrought iron) pivoted at their centre and furnished at the ends with large wheels running on a carefully laid circular roller path at the periphery of the pit, in which the girders are situated. The girders can be raised or lowered by a lever, so as to bring the greater part of the weight on the pivot. At the ends of the girders long hinged projecting handles are provided, by which the turntable is pushed round. Sometimes a rack and pinion arrangement is adopted for turning the table, instead of the handles, but the latter are the simpler and more expeditious means.

Sheds are required for engines engaged in working the ordinary traffic of the line, and these are called running sheds, as

distinguished from repairing sheds, where the locomotives are repaired. The running shed should be so placed that an engine going to it or leaving it may foul the main lines as

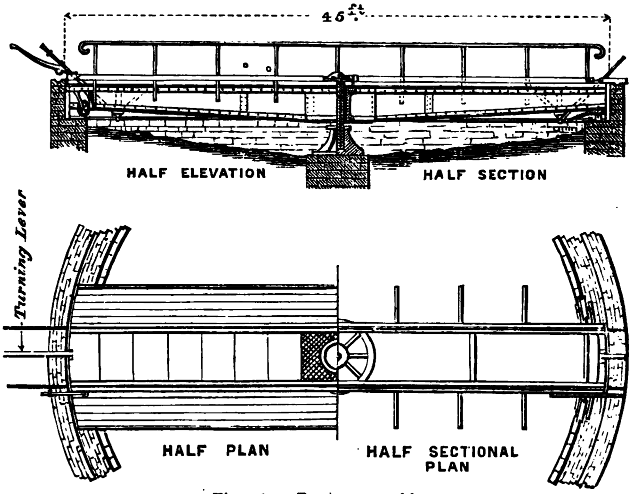


Fig. 163. Engine turntable.

little as possible, and the arrangement of the shed should be such as will permit engines to arrive or depart, without interfering with other engines standing in the shed. The engine turntable is often arranged so that it may give access to different lines of rails in the shed, without the use of long sidings; and the engine sheds are often made segmental on plan thus accommodating the lines radiating from the turntable. This form of shed is somewhat extravagant in space, but it has the advantage of each line being easily accessible. The roof of an engine running shed should be freely ventilated, and when the position to be occupied by the engines can be defined beforehand, vertical pipes open to the air at their upper end, and funnel-shaped at their lower end, are often fixed so that the engine funnel may stand directly under the pipe, and the smoke from the

engine pass easily out of the shed. A small furnace is required in a running shed, in which coals and coke can be kept burning for the purpose of lighting the fires in the locomotives. Water for washing the engines should be laid on to a hydrant fixed in a box below the level of the paving on each side of every engine. Space should be provided for smiths' benches, at which trifling repairs can be taken in hand.

In the shed, pits are required beneath the engines for the purpose of examining the machinery, and outside the shed similar pits are required, in which engines may deposit their ashes before coming into the shed. These pits (fig. 164), which are called ash pits, are usually formed with brick walls and brick bottoms, thoroughly well drained. As there can be no cross ties in an ash pit, great care must be taken, either by the use of long bolts built into the walls, as shown in the fig., or by external struts to prevent the rails from spreading asunder. The drains from an ash pit are liable to become choked by small ashes, and they should be easily accessible, so that they may be cleared out from time to time. Inclined planes should be provided at one or both ends of each ash pit, so that a barrow can be wheeled in and out of the pits to remove the ashes.

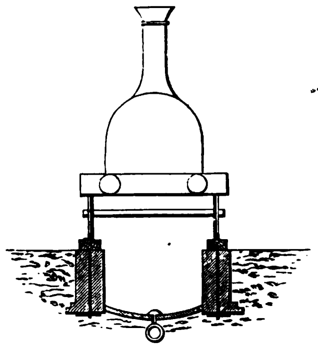


Fig. 164. Ash pit.

A stage for furnishing the running engines with coke is required, and this should be so placed that engines may take in their coke on leaving the running shed, and that engines not requiring to enter the shed may get coke, without *interfering* with engines approaching or leaving the shed.

The coke stage should not be alongside the line of rails leading to the turntable, as this line should be always kept free, so that engines may approach and leave the turntable at all times. A coke stage (fig. 165) is generally about 5 feet above the level of the rails, which height allows of the coke being easily shot into the tender from baskets, in which it is usually placed ready for an engine's arrival at the stage.

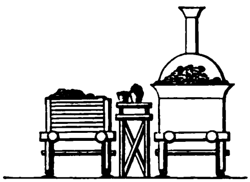


Fig. 165. Coke stage.

A siding should be provided on the opposite side of the coke stage, to that on which the engines arrive and depart, long enough for a number of coke waggons proportioned to the consumption of coke.

A supply of water is required near the coke stage to fill the tanks of the locomotives. The supply is generally given through a water crane (fig. 166) which is a vertical hollow pillar, carrying a horizontal revolving arm and a short pendant leather hose, the pillar being so placed that the arm will swing over the tender. The horizontal arm is often so made

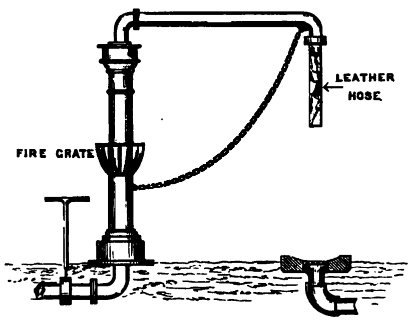


Fig. 166. Water crane.

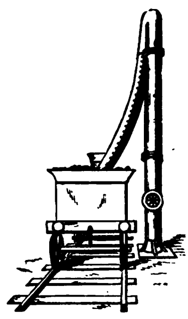


Fig. 167. Standpipe.

that it will when released swing of its own accord to a position parallel to the rails, in order that when not in use for watering engines it may be out of the way of passing

vehicles. Occasionally, instead of a water crane, the water is supplied by stand-pipes (fig. 167), with long pendant leather hose. The stand-pipe must be high, or the angle at which the hose will be when supplying a tender will impede the supply. The valve for regulating the supply of a water crane is generally placed on a short pillar near the crane, but not on it, so that in case of repairs being wanted the water can be shut off altogether from the crane. Occasionally the valve is placed at the top of the crane, so that it can be worked from the locomotive tender which is being supplied; but in that case a second valve is desirable to shut off the water from the crane for repairs. A grate should be provided round the crane or stand pipe, in which a fire can be kept burning in frosty weather.

Ample water tanks (fig. 168) are required at all locomotive depôts and wayside watering stations, and care is required in the selection of the water to be used, as many descriptions of water are by no means suitable for boilers, and will induce priming, or will leave a deposit in the boiler, or will corrode the boiler plates rapidly. A tell-tale, as shown in fig. 168, should be attached to the tank, so that the person in charge of it may have timely warning of any deficiency.

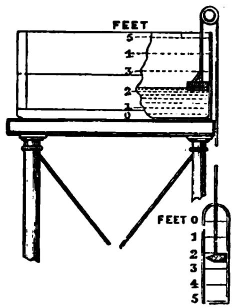


Fig. 168. Water tank and tell-tale.

In some places means are provided for engines to take in water without stopping. This provision is useful not only for fast passenger trains, but also for through goods trains, in order to diminish the delay and inconvenience of stopping even slow trains unnecessarily, and of consequently blocking the line meantime. A trough about a quarter of a mile long is laid between the rails on a level part of the line, and this trough is kept *charged* with water by a self-acting valve. The tender

is provided with a pendant hinged pipe, which can be let down when desired, so that its bottom end, which is open, will in its lowest position be slightly above the floor of the trough, and will point in the direction in which the tender is going, as a ploughshare points in the direction in which the horses drag it. The water is caused, by the velocity at which the pipe encounters it, to rush up the pipe, and so to fill the tender. The rails are laid on an incline at each end of the level portion of the railway on which the trough is placed, so that the trough itself is on a level depressed part of the line between two short inclines. The inclines are of such a length and with such a rise that the end of the pendant pipe will be carried over the end of the level trough without touching it.

Store rooms are required in connection with the engine running shed, with tanks for oil and tallow, and there should be an office adjoining the store rooms for the superintendent of the locomotive depôt, and the store-keeper.

Rooms should be provided near the running shed, for the accommodation of the engine-drivers and stokers, in which they can get their food cooked, and can wait when not on duty on their engines or in the shed. They should be provided with W. C.s and with good appliances for washing, with hot and cold water. Lockers for the reception of the men's clothes, and means for drying their clothes when they come in from a wet journey, should also be provided.

CHAPTER VII.

ROLLING STOCK.

ROLLING STOCK of a railway, as the term is generally accepted, may or may not include the locomotive engines, but no attempt will here be made to describe the engines. It is proposed to refer briefly to the leading characteristics of railway carriage and waggon rolling stock, but anyone who wishes to follow out the subject must apply himself to some of the well-known published works on this important part of railway engineering.

A few words are necessary with regard to the weights which are carried on the wheels of locomotives, as this matter is one which has a most important bearing on the form and material adopted for many parts of railway appliances. The fact that the tractive force of locomotives is almost invariably exerted through the adhesion between the driving-wheels and the rails, due to the weight of the engine, has been already alluded to above (p. 31) and the consequent concentration of weight on one pair of driving-wheels, or, as an alternative, the coupling of two or more pairs of heavily loaded wheels, has been there referred to as a difficulty in working railways which at present seems irremediable. A few well-known examples of locomotives shown in fig. 167, in which the rigid wheel base of each engine or longitudinal distance between the points at which the wheels furthest apart in the rigid frame of the engine, touch the rails are shown. The *driving*-wheel or wheels of each engine are shaded,

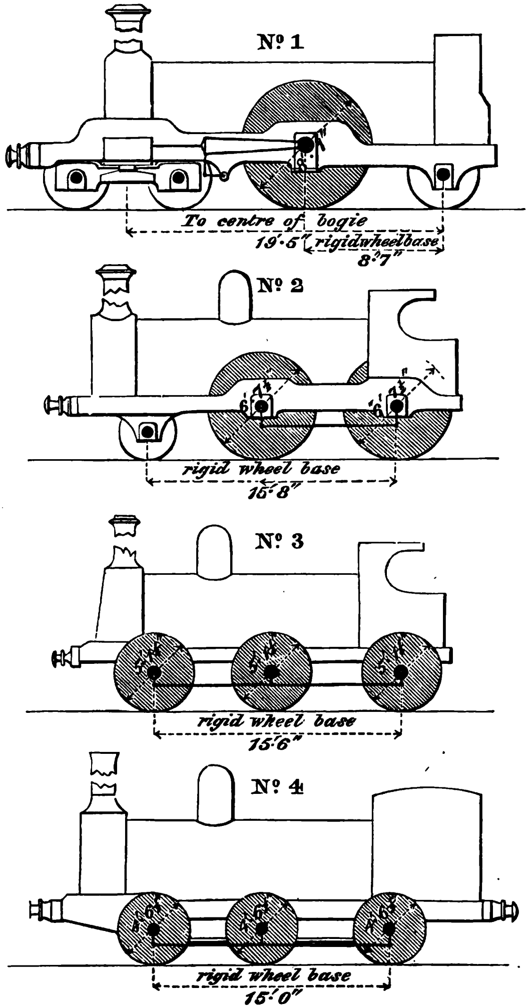


Fig. 169. Outline sketches of locomotives.

and the diameter of the driving-wheels is marked. The weights on each pair of wheels are given in a tabulated form below :—

Weights on Wheels of Locomotives.

	Weight on leading wheels. Per pair.	Weight on driving wheels. Per pair.	Weight on trailing wheels. Per pair.
	tons cwt. qrs.	tons cwt. qrs.	tons cwt. qrs.
No. 1. Fig. 167. Great Northern Railway Express Passenger Engine .	7 10 0 [15 tons on truck of bogie]	15 0 0	8 0 0
No. 2. Fig. 167. London and North-Western Railway Express Passenger Engine .	9 9 0	11 0 0	8 15 0
No. 3. Fig. 167. Great Southern and Western of Ireland Rly. Goods Engine	10 12 1	11 6 3	8 15 2
No. 4. Fig. 167. Furness Railway Tank Engine .	13 16 0	14 11 0	13 8 0

The subject of the locomotives will not be considered further than in this short reference to the weights on their wheels, and the remainder of this chapter will be devoted to the other rolling stock of railways.

Passenger rolling stock consists of first, second, third class, and composite carriages, luggage, and break vans, horse-boxes, carriage trucks, and some special descriptions of vehicles which run with passenger trains, such as invalid and saloon carriages, bullion trucks, post-office vans and tenders. Goods rolling stock consists of waggons of various shapes and sizes, covered and uncovered, for the conveyance of general merchandise, waggons for minerals or ballast, trucks for stone, trucks for timber, break vans, and *special waggons* designed for particular localities and suitable

to particular purposes, such as the conveyance of salt, gunpowder, fresh meat, milk, &c., &c.

The details of the special classes of rolling stock, whether for passengers or goods, will not be referred to, but the construction of the ordinary carriages and waggons in every day use will be briefly discussed. The leading features of the constructional parts are much the same in all cases, and are not materially affected by the modifications by which the stock is adapted to special purposes.

The weights resting on the wheels of carriage and waggon stock are as a rule very much less than the weights on the wheels of engines. The following table will give some idea of the weights on the wheels of rolling stock in ordinary use.

Weights on each pair of wheels of carriage and waggon stock.

	Empty vehicle.			Loaded vehicle.		
	tons	cwt.	qrs.	tons	cwt.	qrs.
First Class carriage	3	6	1	4	0	3
Second Class carriage	3	18	0	5	4	3
Third Class carriage	4	3	2	5	17	0
Covered goods waggon	2	16	1	5	16	1
Open goods waggon	2	12	1	6	12	1
Coal waggon	2	4	2	6	4	2

The rolling stock of railways differs from other wheeled vehicles, both in its design and the use to which it is put, in that the path along which the wheels of railway vehicles travel is accurately defined, and from the curves being laid out with special reference to the nature of the rolling stock, and to the speed at which the trains will travel.

In ordinary rolling stock, as has been explained above (p. 64), the wheels cannot adjust themselves tangentially to the curves of the line. Railway vehicles as generally used are therefore in a mechanical point of view deficient in the respect above mentioned, and the want of power of adjust-

ment involves an unnecessary expenditure of the power of the locomotive in overcoming the friction of the wheel in sliding sideways and in slipping circumferentially on the rail; this is very large compared with the friction encountered by a cylinder simply rolling on a plane. A further evil ensues in the great unnecessary wear and tear both to the permanent way and to many parts of the vehicles which are constructed in the way referred to.

Certain descriptions of rolling stock have, however, been constructed, and especially in the United States, on other principles, which mitigate the evils involved in wheels rigidly fixed to parallel axles. This remedy is applied by what are called bogies, which are as a rule, low four-wheel trucks, with a very short wheel base, and carrying a pivot, on which the ends of the body of the vehicle are supported, in a way similar to that in which the forward part of an ordinary roadway carriage is supported on a pivot between the front pair of wheels. The bogie form of construction will be referred to in due course, but the rolling stock in general use on English railways which has parallel rotating axles on which the wheels are fixed, will be first considered.

The practice of railway companies differs as to the number of wheels placed under passenger carriages, some preferring four-wheeled, and some six-wheeled carriages. As a general rule, goods and other waggons have four wheels, and the same is the case with the majority of carriages, but many of the carriages, especially for express trains, have six wheels.

There can be little doubt that in the case of an accident happening to the springs, wheels, or axles of a carriage, a six-wheeled vehicle is much safer than one with four wheels. If any one of the springs, wheels or axles of a four-wheeled carriage is disabled, the corner or end of the carriage over the disabled wheel or axle will probably drop; but with a six-wheeled carriage this need not happen, as the carriage would still be supported on five or four wheels, and might run a long distance without serious disaster. The disadvantage of six-

wheeled carriages is that, they cannot accommodate themselves to the curves of the line so readily as four-wheeled carriages, for the curve of the line demands that the three wheels on each side should be in a curved line, whereas the attachment of the wheels to the frame of the carriages tends to keep them in a straight line. The necessary accommodation is provided by the clearance between the wheels and the rails, by a certain amount of slackness or play in the several parts of the connection between the wheels and the frames of the carriages, and by some bending of the frames themselves. There is, however, no difficulty in constructing six-wheeled carriages properly, or in working them on railways with reasonably good curves; in fact on many lines the long six-wheeled carriages are specially selected for express trains on account of their steadiness, in addition to their other advantages referred to above. It is to be borne in mind in considering the relative safety of the different forms of carriage, that ordinary stopping trains often travel at some portions of their journey at a speed as high as that of express trains, and that an accident to an ordinary train at such a time would be as disastrous, as one to an express.

The length of the wheel base is an important matter when the mode in which a railway vehicle with six or more wheels passes round a curve is considered, because if the frame and attachments which hold the axles were absolutely rigid, and there were no clearance between the flanges of the wheels and the inside edges of the rails, it would be impossible for the carriage to be worked on any but straight lines. The longer the rigid wheel base, the more clearance and play are required, and therefore, as the amount of clearance and play is more or less a fixed quantity, the length of the rigid wheel base is by this circumstance limited, and must have direct reference to the curves of minimum radius on the railways on which the vehicles are to travel. The frames and the horn plates (which control the axle-boxes)

of locomotives possess great strength and rigidity, in order to support the heavy weights and strains due to the boiler and machinery. The frames, springs, and attachments of the axle-boxes of carriages and waggons, though possessing considerable rigidity, are more yielding than those of locomotives, and the wheel base of six-wheeled carriages can consequently be longer than the wheel base of six-wheeled locomotives.

In four-wheeled vehicles with parallel axles the admissible length of wheel base is governed by the sharpness of the curves of the line, since on that and on the length of wheel base depends the possible obliquity of position of the wheels on the rails; with the amount of obliquity the tractive force required is increased, as also is the danger of the outer leading wheel mounting the outer rail.

Oscillation in railway carriages consists of endways and sideways movements, and of movements resulting from a combination of the two. The endways movement is a longitudinal or pitching motion, resulting from inequalities in the road, causing unequal play of the springs at the two ends of the carriages. The sideways swaying movement is a motion resulting partly from the same cause, occasioning unequal upwards and downwards play of opposite springs, but arising more from the clearance between the wheels and the rails which allows the carriage to move bodily sideways from time to time. Another form of motion which, however, is only occasionally felt, is a vertical oscillation of the whole carriage on its springs resulting from a synchronous series of jolts produced by bad joints in the road or other equidistant imperfections. The sideways motion is that which is now-a-days more generally observed, but in the early days of railways, when short carriages were used, and before the use of the fish-joint, the sensation of pitching was much more common than it is now. The longitudinal pitching motion and the vertical motion have been gradually to a great extent got rid of, as carriages have been made

longer, as the use of six wheels has been more general, and as greater attention has been paid to the permanent way.

Carriages were formerly seldom or never made with more than three compartments, and those compartments were much smaller than those of modern carriages. The internal dimensions of the different descriptions of carriages now adopted as compared with those of 1845 will be referred to below; but, to take one instance, an old first-class compartment was only 5 ft. 5 ins. between the partitions, whereas now it is usually about 6 ft. 3½ ins.; and, whereas formerly a full-sized carriage had three compartments, and was about 20 feet long (including the buffers), it has now four or five compartments, and is from 29 to 36 feet long.

The width and height of carriages have also been increased, in order to meet the requirements of the public, and thus the dead weight of carriages has increased relatively to the paying load which they carry as is shown by the accompanying tables. This matter is of much importance with passenger carriages, but it is of much greater conse-

Comparison of length, width, and weight of carriages in 1875 *and* 1845, *and percentage of paying load in total weight.*

		Length of body outside over buffers.	Width of body outside.	Total weight of empty vehicle.	No. of passengers.	Total weight of vehicle fully loaded.	Percentage of paying load to total weight of fully loaded vehicle. Total weight of fully loaded vehicle = 100.
		ft. ins.	ft ins.	tons cwt.	No.	tons cwt.	per cent.
First Class	1875	27 0	8 4	9 19	32	12 2	17·7
	1845	*16 9*	*7 0*	*4 4*	*18*	*5 8*	*22·3*
Second Class	1875	24 0	8 4	7 16	40	10 9	25·6
	1845	*19 0*	*6 6*	*4 2*	*32*	*6 5*	*34·3*
Third Class	*1875*	27 0	8 4	8 7	50	11 14	28·7
	1845	*17 6*	*8 2*	*4 4*	*40*	*6 17*	*39·0*

Comparison of weight of waggons in 1875 *and* 1845, *and percentage of paying load in total weight.*

Class of waggon.		Total weight of empty vehicle.	To carry	Total weight of fully loaded vehicle.	Percentage of paying load. Total weight of fully loaded vehicle = 100·0.
		tons cwt.	tons	tons cwt.	
Covered Goods	1875	5 9	6	11 9	52·4
	1845	*3 12*	*6*	*9 12*	*62·5*
Open Goods	1875	5 5	8	13 5	60·4
	1845	*3 10*	*5*	*8 10*	*58·8*
Coal	1875	4 9	8	12 9	64·26
	1875	4 5	8	12 5	65·3
	1875	3 19	6	9 19	60·3
	1845	*3 6*	*6*	*9 6*	*64·5*

quence in the case of goods and mineral waggons, as the rates are low and the margin of profit is small in such traffic. The tables give an idea of the weight of the rolling stock of a first-class railway at the present time and 30 years ago, the ratio of the paying load to the total weight of the fully loaded vehicle is in each case given in the last column.

The several parts forming a carriage or waggon may be conveniently dealt with under two heads; first, the undercarriage; and secondly, the upper part or body of the carriages and waggons.

The under carriage consists of:—

1. The underframe, which is the framework by which the body of the vehicle is supported, and by which the weight is transferred to the wheels.

2. The bearing springs, or those between the underframe and the wheels.

3. The buffer springs and the drawbar springs.

4. The axles and wheels.

5. The axle-boxes and bearings.

Underframes.

In the case of carriages the construction of the under-frames, and the sizes of the timbers used, assuming that the

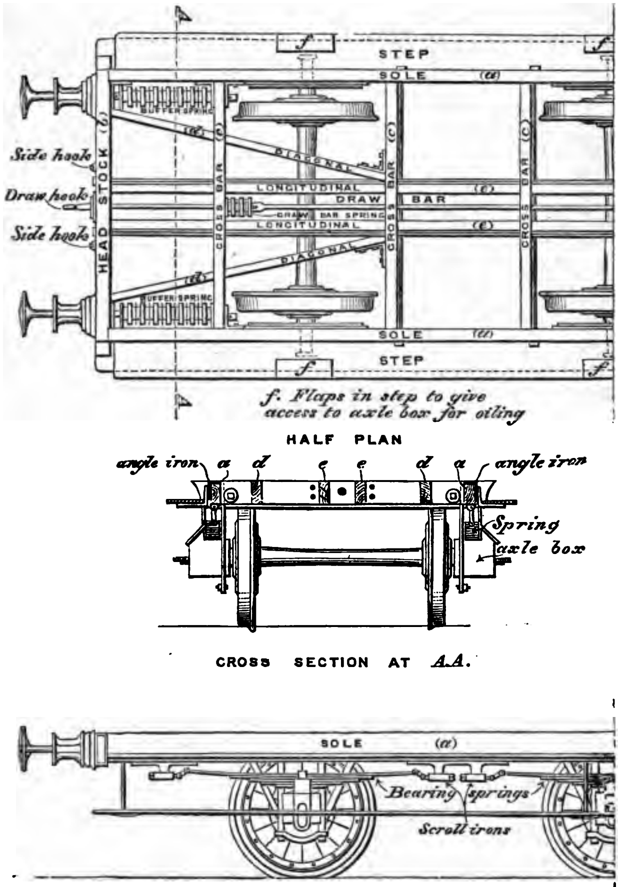


Fig. 170. Underframe of passenger carriage.

lengths of the carriages are the same, are generally similar for all classes of carriages. In the case of waggons, if the

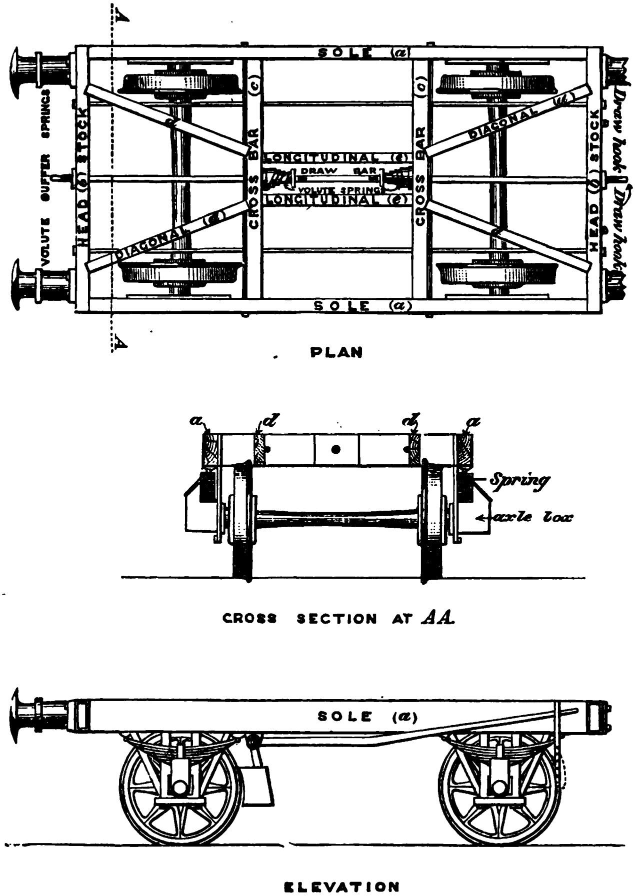


Fig. 171. Underframe of goods truck.

sizes of the trucks are the same, or approximately the same, *and the loads* to be carried by them similar, no essential

difference will be found in the underframe, whatever may be the purposes for which the trucks are destined.

Modern carriages are made long in order to ensure easy running, and consequently the underframes have to be made of considerable strength relatively to their paying loads, to resist the strains due to the extra length of carriages as compared with the shorter length adopted for waggons.

Fig. 170 shows the under carriage of a modern first-class carriage with six wheels, and fig. 171 shows the under carriage of an ordinary four-wheeled goods waggon.

An underframe consists of the following parts, which are distinguished on the sketches by letters corresponding to those in the following list of the timbers composing the frame :—

(*a.*) Soles, which are the side timbers, extending longitudinally from end to end of the frame.

(*b.*) Head stocks or end timbers, which unite the soles at their ends, and with them form the outside timbers of the frame.

(*c.*) Cross bars or transverse timbers, parallel to the head stocks.

(*d.*) Diagonals which, as their name implies, are placed in a diagonal direction, between the head stock and the centre of the frame, so as to convey the strains which come on the head stock to the framing generally, and to prevent any alteration in the shape of the framing.

(*e.*) The longitudinals, which are timbers placed parallel to the soles to strengthen the head stocks and cross bars, and afford intermediate support between the soles for the floor of the body.

The scantlings of the timbers in underframes, such as those shown in figs. 170 and 171, are given in the table on the next page.

The soles have to act as girders to carry the weight of the body from wheel to wheel, and in the case of long carriages the soles are often made with flat plates of iron or

Scantlings of timbers for underframes of Carriage and Waggon Stock.

	Soles.	Head stocks.	Cross bars.	Diago-nals.	Longi-tudinals.
	ins.	ins.	ins.	ins.	ins.
Underframe of carriage. .	11 × 4	11 × 4½	11 × 3½	11 × 3½	11 × 3
Underframe of goods waggon (to carry 8 tons) . .	12 × 4	14½ × 5	12 × 4	12 × 3½	12 × 2½
Do. do. (to carry 10 tons)	12 × 4½	14½ × 5	12 × 4½	12 × 3½	12 × 2½
Underframe of coal waggon (to carry 8 tons) . .	12 × 4	14½ × 5	12 × 4	12 × 3	9 × 3

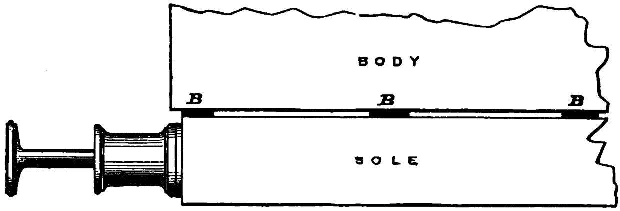
steel (see fig. 173, p. 241), or with deep angle irons (see fig. 170, p. 236), extending in most cases from end to end of the frame, and firmly bolted to the timber.

The junctions of all the timbers are made with strong iron knees and bolts. The greatest care is given to make the frame extremely strong against the various strains lengthways crossways, and diagonally, to which a railway vehicle is constantly exposed.

No expense should be spared in securing sound seasoned timber for the whole of the underframe, as the cost of the labour to construct the frame is greatly in excess of the value of the raw material. The timber generally used for underframes is either teak or oak, both of which are very suitable for the purpose.

The underframe should be protected from the weather and from water soaking into the joints between the timbers in every practicable way, by paint or varnish, and by coverings over the joints. Timber usually decays at joints from water finding its way into the joints, however small the opening of the joint may be. In addition to its soaking downwards, water also finds its way by capillary attraction along a horizontal crack, and it is therefore desirable that the body of the carriage should not rest continuously on the underframe, but be supported by blocks, as shown in

fig. 172. This arrangement allows the air to circulate freely on the top of the underframe, and prevents rot from being set



B.B. Blocks of wood or vulcanized india rubber

Fig. 172.

up. The blocks, which are about ¾ of an inch high, are frequently made of vulcanized india-rubber, which is perhaps further useful in giving elasticity between the body and the underframe.

Many underframes of carriages and waggons have been made entirely of wrought-iron, following the general arrangement of the frames, shown in figs. 170 and 171; but although this material is more durable than timber, and within the limits of the space available a properly constructed wrought-iron frame may easily be made very much stronger than an ordinary wooden underframe, and not much heavier, iron underframes have not been generally used. It is said that repairs to an iron frame are more troublesome than to a timber frame, as any straining of an iron frame bends the whole frame, and the damage cannot be put right again without the use of a forge to straighten the bent parts, and without cutting out rivets, and rivetting up the frame again. And that consequently a strained wrought-iron frame is often scarcely worth the expense of repairs, and that its parts cannot well be worked in for other frames. If a wooden frame be strained, the damage is no doubt often localised at the joints of the framing, and can be comparatively easily set right by taking the frame to pieces, and putting it together

again with perhaps a few new iron knees and bolts. But it must be allowed that these circumstances seem to show the weakness of the joints of a wooden frame, and suggest that the joints of a wrought iron frame can be made so much stronger than the joints of a wooden frame, that a stress which will start the joints of or dismember a wooden frame would be successfully resisted by a well constructed wrought iron frame.

Springs.

The bearing springs are interposed between the frame and the axle-box, so that the carriage may ride easily, and that sudden blows or impulses given to the wheels resulting from inequalities of the road or similar causes may not be transmitted to the body of the carriage. The bearing springs of carriages and waggons are made of steel plates, about $3\frac{1}{2}$ inches wide and $\frac{3}{8}$ inch thick, arranged in the well-known way shown in fig. 173. The spring plates are held together at their centre by a band or link of wrought-

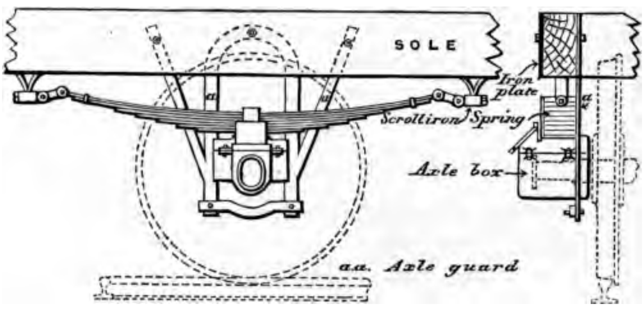


Fig. 173. Bearing spring.

iron, into which the plates are firmly secured, or by a bolt passing through all the plates. The band or link is either bolted down on to the top of the axle-box, or merely fits into a *mortice in* the top of the axle-box, in which it is held

by the weight of the carriage, while the situation of the bottom of the band in the mortice prevents any lateral motion taking place between the spring and the axle-box. The ends of the spring are attached to the sole by brackets, which are called 'scroll irons.'

The length, width, and thickness of the spring plates, and their number, or in other words, the strength of the springs, vary with the circumstances of different vehicles, and also in some cases according to the place which the spring is to occupy in the vehicle. Thus it is said that a six-wheeled carriage travels more easily if the springs over the end wheels are shorter and stiffer than the springs over the centre wheels. The plates of the springs are kept from sliding out of place one on the other in various ways, being sometimes made with a projection or boss, like a small button, on their lower face, which fits into a corresponding hollow on the upper face of the plate below it. These hollows and bosses are usually only placed at the centre of the spring, but sometimes pins in slots are provided at other parts of the spring plates on each side of the centre; if, however, the plates are firmly held together at the centre by the band and the bosses, or by a bolt passing through the plates, no other means of holding the plates together is usually found necessary.

Buffers and Draw-bars.

The buffer springs for carriages were formerly almost universally, and are still, in many cases, made, like bearing springs, of flat steel plates, fixed horizontally at the centre of the frame between the two centre cross bars, as shown in fig. 174. In such cases there are two springs to each carriage, placed back to back, one to receive the thrust of one pair of buffers, and the other to receive the thrust of the other pair of buffers. The buffer rods rest against the ends of the springs, which can turn to a slight extent on their centres, and so if one buffer be pushed in, the opposite

buffer is pressed outwards by the opposite end of the spring. The draw-bar of the carriage, which is a bar in prolongation

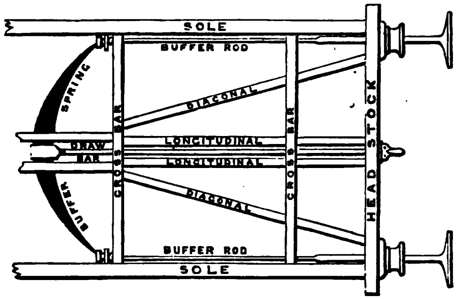


Fig 174. Half plan of underframe showing transverse buffer and draw-bar spring.

of the hook by which a carriage is attached to its neighbour, is generally made fast to the centre of the buffer spring, which thus yields slightly to the tractive force exerted on the hook of the draw-bar.

Carriages are attached one to the other by what is called a coupling (fig. 175), which consists of two elongated links

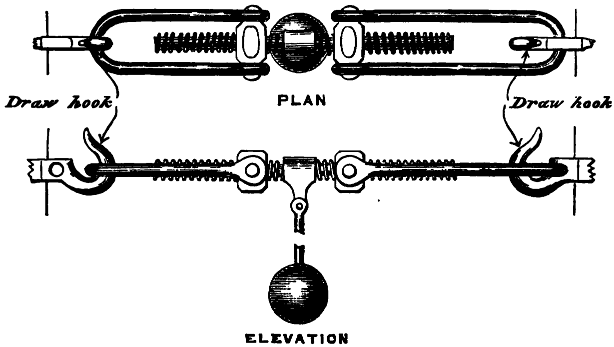


Fig. 175. Screw coupling.

of wrought iron, united by a right and left handed screw, which *can be* turned round so as to lengthen or shorten the

coupling. Attached to the screw is a pendent lever with a weight on its end to assist in its being turned round, and when carriages are to be coupled together, the screw should be turned round sufficiently often to bring a good strain on the buffer springs. When a train of carriages tightly coupled together is going round a curve, the buffers on the inside of the curve are pushed additionally inwards, and the pressure between the opposite buffers is relaxed. In order to prevent oscillation, all the buffers should be at all times pressed tightly against one another. This object is accomplished even on sharp curves by the transverse springs, because the pressure inwards of one buffer causes an outwards pressure of the other buffer. The buffer rods and the draw-bar, which act antagonistically the one to the other, on the transverse spring, are provided with stops, so that the former cannot go out, and the latter cannot come in more than a sufficient amount; this enables the transverse spring to be always kept with a considerable amount of initial strain upon it, and to be thus always ready to react with vigour against the strains which may come upon it.

The long plate springs across the carriage are, however, cumbrous, and expensive, and are being to a great extent

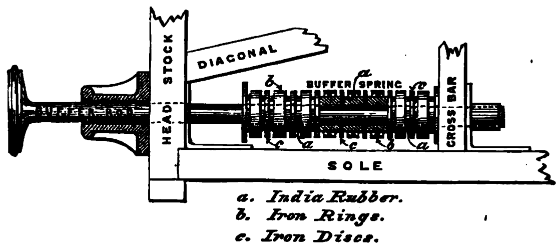


Fig. 176. India-rubber buffer springs.

superseded by india-rubber springs, shown in fig. 176, which are formed of a number of discs of vulcanised india-rubber, enclosed in iron rings, and placed between thin discs of iron.

The india-rubber discs are from $2\frac{1}{2}$ to 3 ins. thick, and from 6 to 8 discs form a buffer-spring of a modern carriage. The buffer as it is pushed inwards by the pull of the coupling compresses the india-rubber, which resumes its original dimensions when released from pressure. With india-rubber springs there is no action as described above of one buffer being pushed outwards by its opposite companion being pushed inwards, but it is stated that this action is not required, because if the springs be properly made, both buffers are compressed by the screw couplings sufficiently to insure that when the train is going round curves of any ordinary radius the outer buffers will always be pressing against its opposite neighbour by the resilience of the india-rubber.

The draw-bar, as shown in fig. 170, is in such cases also furnished with india-rubber disc-springs. The two draw-bars of a carriage or waggon are frequently united at their ends, so as to form a continuous bar beneath each vehicle; and thus when the draw-bars are attached together by the screw coupling between the vehicles, the traction of the engine is exerted on a continuous tightened-up chain to which each vehicle is attached, and no accumulative strain is put on the framing of the vehicles in the fore part of the train. Chains, called side-chains, are fixed to the head-stocks on each side of the hook of the draw-bar. These chains are attached together by the hooks at their ends, and are only intended to come into action if any coupling or draw-bar break. In the case of waggon stock the buffer and draw-bar springs are often made with volute springs, as shown in fig. 177, which are formed of steel plates bent into a helical form.

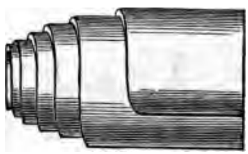


Fig. 177. Volute spring.

Goods trucks are, as a rule, not coupled tightly together by a screw coupling, but are merely attached by chains *which have* a considerable amount of slack when the buffers

are in contact. This arrangement is adopted partly for convenience of coupling and uncoupling, but more for the increased facility which loose coupling affords for starting a heavy train. With loose couplings the engine starts each truck separately, and, to start the after-part of the train, the power of the engine is assisted by the momentum of the engine and of all the trucks which have already started and have gathered way.

Loose coupling thus permits an engine to work a heavier train than if tight screw couplings were used, because the power required to overcome the adhesion of a standing train is greater than the power necessary to drag the same train when in motion. In consequence of the frequent stopping and starting of a goods train in shunting and stopping at stations, this is an important matter ; but it is a question whether the advantage of starting easily, and the consequent economy in locomotive power, is not bought at too heavy a sacrifice. The effect of loose coupling is to cause a series of jerks on all the draw-bars in starting, and a series of violent concussions on the buffers when the train is stopped, which are most seriously damaging to the rolling-stock, and frequently to the contents of the trucks. Further, the trucks of a loosely-coupled train swerve continually from side to side on the rails, and produce much extra wear and tear on the permanent way. These drawbacks counter-balance to a great extent, if not entirely, the saving in locomotive power. Saving of locomotive power, however, can be appraised with accuracy, while the cost of the wear and tear of rolling stock and permanent way can only be a matter of estimate, and thus loose coupling is still customary for a great part of the goods and mineral traffic of this country.

The present system of coupling, either by the ordinary screw coupling or by loose coupling, involves the necessity *of a man* going between the trucks to attach the coupling to *the draw-bars,* which is a very dangerous service, and is the

cause of great loss of life among railway servants. A great need is a simple and inexpensive system of coupling, which would enable the trucks or carriages to be attached to one another without the danger of the men being crushed between the buffers.

In some modern carriages, in order to save the expense and weight of a pair of buffers, and also to make the trains shorter, there are only two buffers to each carriage, *i.e.* a pair at one end, and only a buffer plank or a pair of round discs of wood fixed to the head-stock at the other end.

Some goods and mineral waggons are made without any buffers, the soles being merely prolonged beyond the head-stocks. This arrangement may perhaps save slightly in the first cost of the buffers, but it is not to be recommended, as the concussion of such trucks unrelieved by any kind of spring is seriously damaging to the whole under-frame. The saving in first cost is rather apparent than real, as the frame ought to be made stronger if no buffers are used, or else it soon wears out. There can be little doubt also that in the diminished wear and tear of rolling-stock, in the case of loosely-coupled waggons, buffers amply repay their cost.

Some carriages are made without any spring buffers, and are coupled together tightly at the centre of the head-stock without any slack in the draw-bars. This arrangement is common in the United States and in other countries where the long American carriages are adopted. Tight coupling has also been used for some time past in England on the London, Brighton, and South Coast Railway for the ordinary description of passenger carriages, and fig. 178 (see next page) shows the arrangement of the tight centre coupling adopted on that railway. A hard wood block (*a*) surrounded on all sides but on its rear with iron, is placed at the centre of every head-stock; a flat coupling-bar (*f*) runs through the centre of the block, and is attached at either end by a pin (*c*) to a short draw-bar (*d*) which transfers the tractive pull to the frame of the carriage. At the other end of the draw-bar there is a screw (*e*) with a

nut on it, which is turned to tighten up or slacken the coupling by a ratchet spanner (*f*) hanging vertically below the

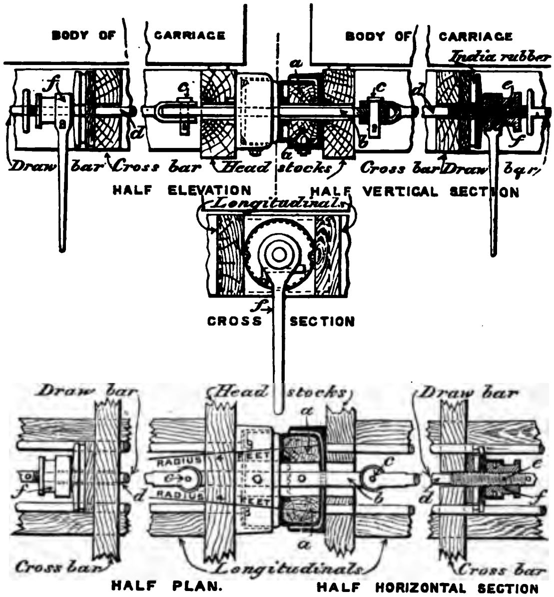


Fig. 178. Central buffer and springs.

carriage. This adjusting nut presses by a ball and socket joint against the frame of the carriage, and allows of a small amount of necessary horizontal or vertical play of the coupling. To couple up two of these carriages a man goes beneath the carriage, and puts the pin through the holes in the links of the draw-bar and in the coupling-bar. A few turns of the nut by means of the ratchet spanner then tighten up the coupling, and the carriage is rigidly connected with its neighbour. The arrangement shown is used for short traffic trains which are not uncoupled for months together. If it were necessary to couple and uncouple frequently the pin might be put in from above, through the floor of the carriage.

A train of carriages coupled together in this way resembles one large articulated carriage, and its length cannot alter under any circumstances. It is an important question whether in a collision a train coupled up tightly and with no buffers would or would not be found a bad arrangement for the passengers. The diversity between the modes of connecting carriages and the essential difference between spring and rigid buffers makes it important to consider the principles that ought to govern this subject.

Buffers have two duties to perform, the first is, that with the help of the coupling, whether elastic or non-elastic, a considerable frictional pressure may be established between their ends, so that while the ends of the carriages can slide past one another as is necessary when the train is entering on or leaving a curve on the railway, the friction may be so great that the carriages shall not be free to oscillate independently. The effect of tight coupling on the steadiness of the train will be appreciated by anyone who has travelled in a carriage both before and after the coupling has been properly screwed up. The second purpose of buffers is to mitigate the effects of collisions. In providing against collisions the great thing to be aimed at is to provide an elastic medium in compressing which the momentum of the train should as far as possible be absorbed, and the longer the time which can be occupied in the process, provided that the speed of the train be meantime rateably reduced, the better. There should be, however, no recoil of the compressed medium whatever the medium may be, and this is where the ordinary buffer fails in its work. The recoil of the buffer springs in a collision often does a great deal of damage, and buffers, if they are used at all, ought to be so made that when compressed by more than the pressure due to tight coupling or to the ordinary application of the breaks, or to running down an incline, the buffer springs should be incapable of free recoil, and there are no great difficulties in this being done.

Another objection to the ordinary spring-buffer even if it were made non-recoiling, is, that in severe collisions the longitudinal stress thrown on the buffers is extremely great as compared with the strength of the buffer-springs, so that they yield readily, causing the behaviour of the carriages of the train to be to a great extent the same as would be the case if the carriages were without buffers, and were arranged in a train with an interval between each carriage, as in the case of loosely coupled mineral-trains. Thus, in the case of a severe collision of an ordinary train with an obstacle, each carriage of the train is, to a certain extent, running free till it comes into abrupt collision with the carriage immediately in front of it, and so experiences a resistance compounded of the resistance due to the obstacle and of the resistance due to the weight of all the carriages in front of the carriage in question; while the obstacle and the already comparative stationary carriages have only at each successive impact to receive the blow of a single carriage. If, however, the carriages, instead of running with an interval between each, had been touching each other the combined mass of the whole would have either forced its way sufficiently into the obstacle or would have crushed up the leading part of the train, so as in either case to form a long compressible buffer, relieving the passengers in the rest of the train from severe stress. Results similar to those of severe collisions exhibit themselves in no small degree in minor collisions, where the obstacle is much less than sufficient to completely arrest the progress of the train.

In estimating the advantages and disadvantages of the system of tight coupling without buffers, it must also be remembered that the tight coupling may be extremely valuable in collisions in preventing the carriages from commencing to mount one over the other, whereas the ordinary couplings which hang loosely when the buffers are compressed oppose at such times no obstacle to relative vertical movement of the carriages. But as ordinarily there is with the

tight coupling no special elastic medium to absorb, in the case of a collision, the momentum of the train, it is to be expected that the carriages nearest to that end of the train at which the collision takes place will suffer severely.

The best theoretical arrangement would probably be to concentrate the buffing arrangements at the head and tail of the train, and to couple up the intermediate carriages tightly; but in that case the vehicle carrying the buffing arrangement should be of considerable length, and should be so constructed that in the event of a severe collision it should, while being crushed, take up the momentum of the train before any serious harm happened to the rest of the carriages or to the passengers. Probably a buffing carriage which should be designed to be destroyed in the case of a severe collision could be made satisfactorily to fulfil the purposes of a passengers' luggage van, the guards in such a case being placed at each end of the central part of the train.

Wheels and Axles.

The wheels and axles of rolling stock are very much of one general type throughout this country; but there are considerable differences in detail. One important point of similarity consists in both wheels being fixed to the axle, so that the wheel and axle revolve together. In a roadway vehicle the axle does not revolve, and each of the wheels is capable of being turned round on the axle rapidly or slowly without affecting the other wheel. With wheels of this sort, when a vehicle is travelling round a curve the outer wheel revolves as much faster than the inner wheel as is properly proportionate to the difference between the length of the path traversed by the outer wheel and of that traversed by the inner wheel. When both the wheels are fixed to the axle, as is the case with railway rolling stock, the outer wheel must when on a curve, unless the two circumferences be different, revolve too slowly or the inner wheel

too fast. The excess or deficiency of speed is made up by the wheel slipping on the rail. This sort of action, in spite of the attempt to correct it by the use of the conical wheel, takes place largely on railway curves, and there is further a great amount of sideways sliding in consequence of the axles not being always radial to the curve. These matters have been already referred to above (in Chapter II. p. 64), and it is only necessary here to advert to them as admitted facts which have a powerful influence over the design of ordinary railway rolling stock.

It is manifest that the slipping cannot take place without torsion of the axle, and consequently the axle must be made strong enough to resist such torsional strains, in addition to being equal to its other work. A railway axle therefore is made of great strength and must be of the best quality of wrought iron, or of mild steel. The usual shape is shown in fig. 179. The parts of the axle projecting beyond the wheels, on which the weight of the vehicle rests, are called

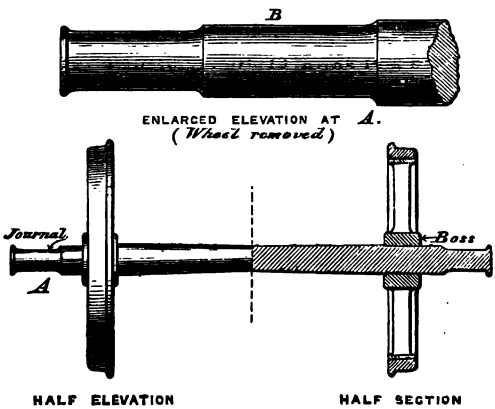


Fig. 179. Railway wheels and axles.

the journals, and are accurately turned in a lathe, great care being given to ensure the smoothness of their surfaces.

Close to the journals, but nearer to the centre of the axle, are the bosses or places on which the wheels are fixed, and these are also turned in a lathe.

It will be observed in the large scale drawing of the end of the axle (fig. 179,) that there are no sharp angles where the diameter of the axle alters, but that all alterations of diameter are made gradually by means of a small curve which is technically called a 'radius.' This is a matter of much consequence, not only in axles but in all parts of structures exposed to high strains, and the necessity for there being no abrupt alteration of form is the greater when the part of the structure in question is subjected to great vibratory or reciprocating strains. The constant breakage of railway axles in the early days of railways was the cause of attention being directed to this subject. Axles were at that time generally made with sharp angles at the changes of diameter, as shown in fig. 180, and it was found that they

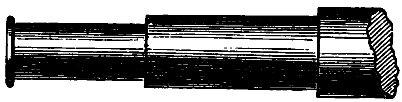


Fig. 180. Axle with sharp angles.

frequently failed at the sharp angles, the fracture almost always showing signs of gradual rupture having preceded the failure. When the matter was investigated scientifically, it was seen that the abrupt change of form was the cause of the failure, and that merely adding to the sizes of the axles did not get over the difficulty. It was shown both by calculation and experiment that if an iron bar of a given uniform section will support a given weight, a bar of the same section, but forming one end of a bar of larger section, will, if the change of section be made with abrupt angles, break at or near the point of change of dimension, with a weight considerably less than in the former case. This matter is one which requires to be remembered by all

engineers, and particularly by those who have to design rolling stock of railways, and engines of all kinds.

The axles of rolling stock are generally made of high class wrought iron, such as Lowmoor or Bowling iron, or else of steel of a mild character, with a small percentage of carbon. A good railway axle should be capable of being bent double when cold without fracture, and great care is necessary when steel is used to secure a suitable quality of metal.

The axle is generally made smaller within the bosses of the wheel than behind the backs of the wheels, as shown at B in the enlarged elevation in fig. 179, but on some railways the axles are made of the full size, or slightly larger, within the wheel than elsewhere, in order that there may be no shoulder behind the wheel to act as an impediment to frequent examination of the axle at a place where cracks are liable to commence.

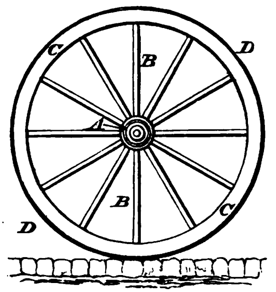


Fig. 181. Roadway wheel.

A wheel of an ordinary roadway vehicle consists of the following parts (fig. 181):—

A, the nave or boss, B the spokes, C the felloes or outside ring into which the spokes fit, D the tire which is put on around the felloes. The nave, spokes, and felloes form the framework of a roadway wheel, and the purpose of the tire is to hold the felloes and the rest of the framework together, and at the same time to protect the felloes from being worn away by attrition on the road. The construction of a railway wheel differs from that of a roadway wheel in the tire of a railway wheel combining the chief functions of the felloes and the tire of a roadway wheel, the tire resembling a continuous felloe *rather than* the tire of a roadway wheel.

The wheels of railway rolling stock are of the well-known form shown in fig. 182, with a flange to prevent the wheels from leaving the rails. In the early days of colliery

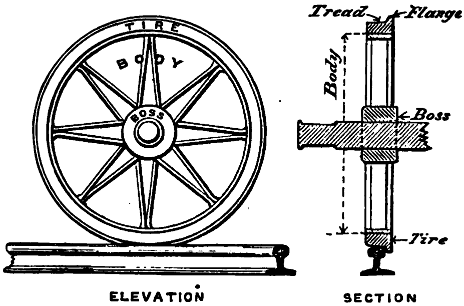


Fig. 182. Railway wheel.

tram-roads the wheels of the trucks were flat, and were guided and kept on the iron plates on which the wheels ran by a flange projecting upwards from the flat plate, as shown in fig. 183, and it was not till many years afterwards that wheels were made with flanges.

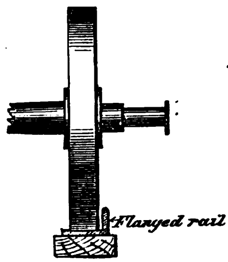


Fig. 183. Flat wheel and flanged rail.

The technical names for the parts of a railway wheel are as follows :—The boss is the centre portion into which the axle fits, the tire is the outside ring, the body is the part between the boss and the tire. The 'tread' of the wheel is the part which runs on the rails; the 'flange' is the narrow part of larger diameter than the tread, which consequently extends downwards below the top of the rails; the throat is that part of the tire at which the flange joins the tread; and the back of the wheel is the portion of the tire which, when the wheel is in its position on the axle, is nearest to the opposite tire. Thus the distance

between the backs of opposite wheels is the shortest transverse distance between any part of the flanges of opposite wheels, and the distance between the throats is the longest distance between any part of the flanges. The latter measurement is (as has been explained above, Chapter II. p. 29) of great importance as respects the gauge of the permanent way; the measurement between the backs of wheels is of equal importance in connection with the position of guard rails, check rails, and crossings.

The distance between opposite wheels and the form of the tires are made to correspond with a standard or gauge (fig. 184) for carriage wheels, which is the complement of

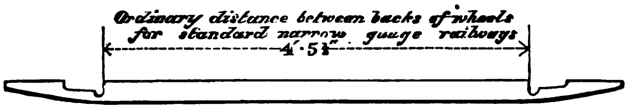


Fig. 184. Carriage wheel gauge.

the platelayers' gauge, and all railway wheels are constantly tested to ascertain that they have not deviated from the leading dimensions of the gauge to which they originally conformed. The flange of the wheel is continually wearing away at the throat under the friction between the wheels and the rails, so that the distance between the throats is constantly varying; but there is no appreciable wear and tear of the backs of the wheels, against which there is no constant friction. Thus the distance between the backs remains always the same so long as the wheels are in their proper position on the axles, and consequently the gauge, when it is applied between the backs, shows how much the flange has been worn in the throats and also whether the wheels retain their proper positions on the axle.

The boss of a railway wheel is generally made of cast-iron, but occasionally of wrought-iron, and is accurately bored to fit the axle. The wheel is secured to the axle *either* by means of a key, or the key is dispensed with, *and the boss* of the wheel being bored smaller than the

diameter of the axle, the wheel is slightly heated and forced on to the axle by hydraulic pressure, the fit being such that the wheel, when it is cold and shrunk, remains tightly fixed in its place. The key is objectionable as weakening the boss, and in the risk there always is, in this mode of fastening, of a crack being commenced, or of some damage being set up in fitting and driving the key home.

The bodies of railway wheels are in this country usually made either of wrought-iron in the form of spokes, or of solid wood. The wrought-iron bodies are made by bending the spokes so that one piece of iron forms half of two spokes and part of the periphery of the body. These bent pieces are bolted or rivetted to each other, and their ends are secured to the boss or the boss itself is cast round the ends of the spokes. The wheel, which then consists of boss and body, is turned in a lathe to the proper dimension to fit the inside of the tire. Three spokes and a tire are shown so arranged in fig. 185.

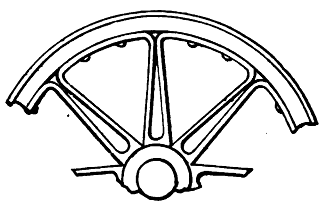


Fig. 185. Portion of iron-bodied wheel, showing arrangement of spokes.

The body of the wheel is often made slightly larger than the inside of the tire, and, in order to fix the tire on the body, the tire is heated so as to expand it sufficiently to receive the body. This method is objectionable on account of the uncertainty of the amount of the strain which may be so placed on the tire, and it is particularly to be deprecated in the case of steel tires. Occasionally the insides of the tires and the outsides of the wheel bodies are turned with a slight taper, and the wheel is forced into the tire by pressure, both being cold. The best mode is probably to turn the wheel body and tire cylindrically to accurate gauges with exactly equal diameters, and to force the tire on to the body without shrinkage. After the tires are forced on they are attached to the bodies by

various methods. Before, however, referring to these methods it is well to describe the other modes in which the bodies of wheels are made.

Spokes are objectionable in a railway wheel from the unnecessary resistance occasioned by their beating the air in their rapid revolution, and from their consequently raising the dust from the ballast, which finds its way into and damages the axle bearings. Solid wheels, which are free from these objections, and which possess the further advantage that they support the tire continuously, are therefore generally adopted for all high-class carriage and waggon stock. There are, however, a very large number of iron-spoked wheels still remaining, and as the body of a wheel wears out slowly, this description of wheel will probably be in use for many years to come.

The solid bodies of wheels are made of various materials, but that usually adopted is wood, well seasoned, and put together in sectors of a circle, with the grain as far as possible radial, as shown in fig. 187. After the body of the wheel and the boss have been put together they are placed in a lathe, and the wooden disc is turned down so that it may be slightly larger in diameter than the internal diameter of the tire. The body is then forced into the tire by hydraulic pressure. Wood is an advantageous material for the body, as it not only acts as a cushion and gives a good continuous support to the tire, but also, when placed with the grain endways to the circumference of the wheel, facilitates the application of the best modes of attaching the tire to the body.

The importance of the subject of attaching the tires of railway wheels cannot well be over-estimated when one considers the consequences which have resulted from breakages of the tires of railway wheels. The early mode of fastening tires consisted of passing rivets or bolts completely through the tire, as shown at A in fig. 186, a rivet-head or nut being placed on the inner side of the ring of the body. This

is most objectionable, as any holes through the tire weaken it seriously, and this objection is aggravated by the necessity that the whole of the part of the bolt or rivet within the tire should be formed with long sloping or dovetail sides, in order

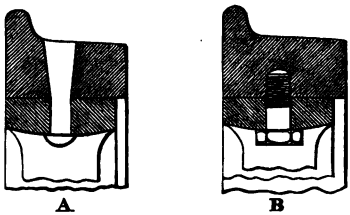


Fig. 186. Tire-fastenings. Rivets and bolts.

that as the tire wears away the hold of the bolt or rivet may not be destroyed. In some cases the tire is fastened by screws passing through the ring of the body of the wheel and tapped into the substance of the tire (B, fig. 186), but these are almost as objectionable as bolts passing through the tire. A still more serious objection to rivets or bolts is that at best they can only hold the tire in their immediate neighbourhood, and if a fracture takes place between two rivets a piece of the tire may completely leave the body.

Many ingenious plans have consequently been brought forward for affording a continuous attachment between the tire and the body. The arrangement which has been the greatest success, and has been generally adopted, is that invented by Mr. R. C. Mansell, of the South Eastern Railway, and shown in figs. 187, 188 and 189. The mode in which the parts are put together, and the way in which they act, is as follows :—

The tire is rolled with two grooves, *g g* (fig. 187), one near each edge, and the body of the wheel is generally, but not always, made of wood, as already described. A wrought-iron ring, having a continuous flange at its outer periphery, is then placed on each side of the wheel, and the flanges on the rings fit into the grooves in the tire. The two rings, which

are called retaining rings, are firmly bolted together by bolts passing through both rings and through the wooden

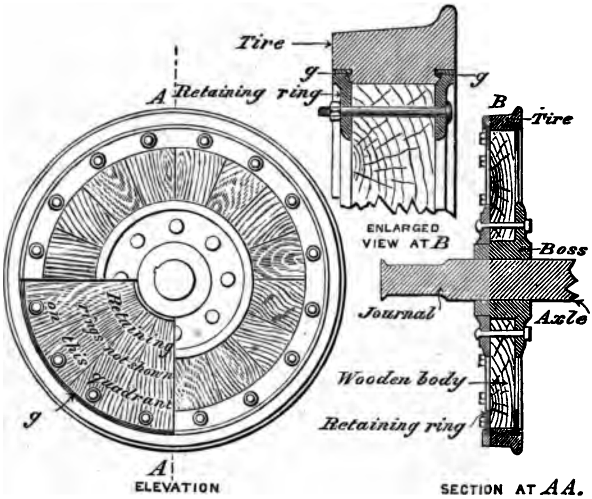


Fig. 187. Mansell's wheel.

body, and so grip the tire continuously. Every part of the tire is thus held fast, so that if the tire breaks into several pieces each piece is held to the body by the two continuous rings.

It often happens that though railway companies wish to adopt the continuous fastening for the tires, they cannot discard all their iron-bodied wheels. Moreover, for wheels of break vans, which have to sustain the local pressure of the break blocks, and for engine wheels, wooden bodies are not so suitable as iron bodies, which are more strong and unyielding. Such wheels require very good holding for the bolts which keep the retaining wheels together, in order to prevent circumferential movement between the rings and the bodies. Fig. 188 shows a means of applying the continuous ring fastening to iron-bodied wheels by placing the bolts of the retaining rings in the angles formed between

the spokes, and the circumference of the wheel. In many cases where the ring fastening is applied to iron-bodied

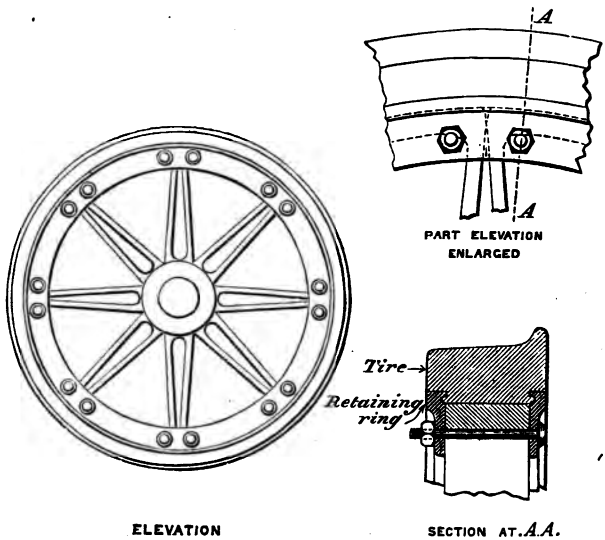


Fig. 188. Iron-bodied wheel, with retaining rings.

wheels, a ring of wood is interposed between the tire and the iron body of the wheel, as shown in fig. 189. The annular cushion of wood in this case is generally about

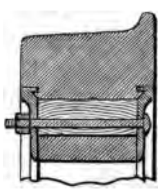


Fig. 189. Iron-bodied wheel, with annular cushion of wood.

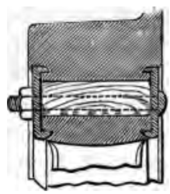


Fig. 190. Retaining rings with double flanges.

2 inches thick, and is placed with the grain of the wood parallel to the circumference of the wheel. Fig. 190 shows

a modification of the form of ring adapted for iron wheels, in which the retaining rings have a flange at both their inner and outer circumference.

Fig. 191 shows a variety of other well-known arrangements for fastening wheel tires, but those which have been illustrated and described above in detail are perhaps the most efficacious of all at present known. Those shown in fig. 191 are more or less similar in principle to that of Mr. Mansell in the idea of an annular groove in the tire, but are in other respects different. The sketch C, fig. 191, shows a square groove in a tire into which an annular projection on the edge of the body fits, but this is dependent for security on bolts passing through the body and into the tire, which, as has been explained above, is objectionable. The sketch, D, also shows a body with a square annular projection on it and an annular groove in the tire; in this case the body is held to the tire by dovetail-shaped fastenings, which are not in the form of a continuous ring, but are short fastenings, one of which is placed between every pair of spokes. This is objectionable on

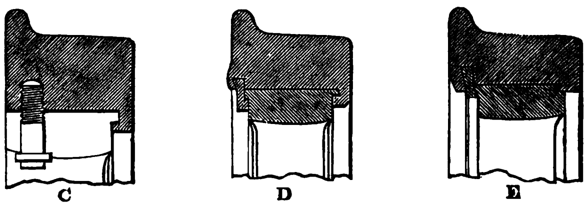


Fig. 191. Tire-fastenings.

two grounds: first, the dovetail grooves and fastenings cannot be relied on to make a tight fastening so well as square grooves and through bolts; and, secondly, no fastening which is not continuous round the circumference of the tire is satisfactory. The third arrangement (sketch, E) is that *known* as the Gibson wheel, and in this the fastening ring *is continuous*. This fastening is, however, entirely depen-

dent on the dovetail-shape of the groove in the tire and of the ring, and the plan is objectionable on that ground. In the cases of the arrangements D and E the side of the tire at the back of the wheel is rolled, so as to leave room for the insertion of the dovetailed fastening, and the tire is hammered down on to the dovetail fastenings when they have been placed in position.

Wheels have been made extensively in America and in some other countries of cast-iron throughout, and the part forming the tire is in that case chilled, so as to harden its surface, and the wheels are very carefully annealed. Cast-iron wheels have, however, not been adopted in England for anything but mineral waggons or other vehicles intended to travel at low speed; but it is not easy to see why, if they are successful in America, they should not be equally successful here. The quality of metal used and the mode of manufacture adopted for cast-iron wheels require special knowledge, experience, and care, which have been more completely given to the subject in America than in England; and possibly this circumstance may account for the diversity of the practice of the two countries.

Axle Boxes and Bearings.

The axle-box and bearings are very important parts of rolling stock, as upon their form and treatment the well-being of the stock, the tractive force required to propel a train, and the comfort of the passengers, greatly depend. The bodies of railway rolling stock are supported on the journals of the axle outside the wheels, and are therefore different to the bodies of roadway vehicles, which are always supported within the wheels. The width of the base of the supports of the bodies of railway carriages or waggons on their axles is therefore the width between the journals, and is not necessarily defined by the gauge of the railway, because the journals, provided they be made strong enough

may project, as indeed they always do, considerably beyond the face of the wheel.

The wheels of railway vehicles, so long as no accident occurs, are always in contact with the rails, even at the highest speed, and oscillation of the carriages is not upon a 4 feet $8\frac{1}{2}$ inches base, but upon a base of 6 feet 10 inches, which is the ordinary transverse dimension from centre to centre of the springs resting on the journals.

The springs rest on the top of the axle-box, and the axle-box rests on a brass bearing which is placed on the journal, as shown in fig. 192. The friction between the carriages and the wheels takes place, therefore, between the iron or steel journal and the brass bearing. The length of the journal is usually about eight inches, and its diameter $3\frac{1}{2}$ inches. The brass bearing is about the same length as the journal, and embraces about $\frac{1}{3}$rd of its upper circumference; white metal is frequently let into the face of the brass bearing, being suitable for resisting the friction of the journal, and less liable to become heated.

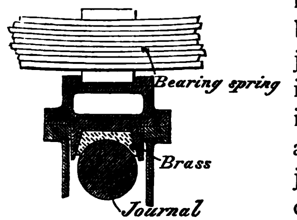


Fig. 192. Axle bearing.

The great points aimed at in a good axle-box are, good lubrication of the brass bearing, and the exclusion of dirt and dust. Without constant good lubrication the brasses get heated, and the surfaces of the brasses or of the journals are destroyed. The lubricants used are either specially prepared grease or oil of different kinds. The former was the original lubricant adopted on railways, and is still much employed, though oil has by this time been

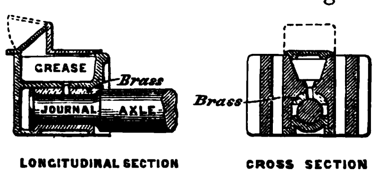


Fig. 193. Grease axle-box.

proved to be more efficient. A grease axlebox is shown in fig. 193. The grease is inserted in the upper part of the box through a small flap, which has a spring, to keep it closed when shut, and there are holes through the brass, down which the grease trickles directly on to the surface of the journal as the axle and brass become warmed by the rotation of the journal. One great objection to grease as a lubricant is that, being applied from the top, it carries down with it on to the journal any impurity or dirt which may find its way into the upper part of the axle-box.

Lubrication by means of oil is usually by capillary attraction upwards. Fig. 194 shows one out of many arrangements for oil lubrication. The oil fills the lower part of the axle-box and also the interstices of an elastic horse-hair cushion, or of a woollen pad pressed upwards by small springs resting on the bottom of the box. On the pad or cushion a worsted pad is placed, with tapes like lamp-cottons which convey the oil from the pad to the journal, the under side of which the tapes touch. Fig. 195 shows an axle-box which is adapted for either grease or oil. It is

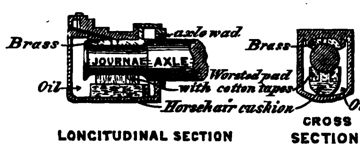


Fig. 194. Oil axle-box.

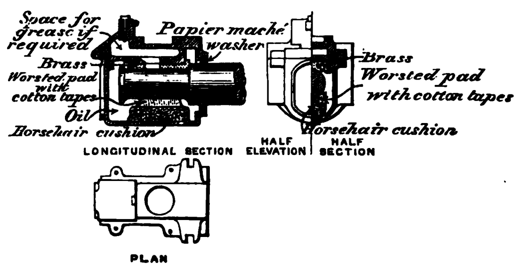


Fig. 195. Axle-box for oil or grease.

useful to have the power of applying grease in cases of neces-

sity to axles which are ordinarily lubricated with oil, in order to meet the troublesome but not unusual case of axles getting heated in running. If an axle lubricated with oil gets heated, it occurs in consequence either of the oil being deficient in quantity or quality, or of something being wrong with the pads and tapes. In either case the first result of a hot axle is that the tapes and pads are damaged by the heat, and cease to fulfil their purpose; it is then useless to put more oil into the axle-box until the pads have been replaced, which operation has to be done at leisure, and necessitates the removal of the carriage from the train. If in such cases means are provided for temporarily lubricating with grease, which requires no pad and tapes, the carriage can continue on its journey.

It is extremely difficult to keep dust and dirt from entering the axle-box, and many contrivances are adopted to prevent it as far as possible. The most usual plan is to have an annular wad of wood or papier-maché placed in a groove in the back part of the axle-box. This wad is made in two halves, divided horizontally, which are joined by bevelled edges. The lower edge of the wad is pushed upwards in the groove in the axle-box by light springs, on which its lower edge rests, and the upper half of the wad is kept in contact with the lower half by its weight. An axle-wad is shown in fig. 196.

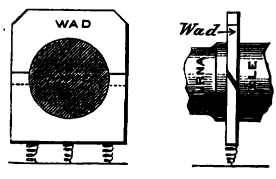


Fig. 196. Axle-wad.

The axle-box is kept in its position relative to the underframe of the carriage, by the springs and by the axle-guards or horn plates (shown in fig. 171), which are wrought iron or steel plates bolted to the soles, and projecting downwards below the underframe, in grooves in the sides of the axle-box. The axle-guard projects below the bottom of the axle-box, and a longitudinal

bar is bolted to the lower ends of the guard, to connect together the guards on the same side of the carriage. The upper ends of the axle-guards are spread out in various ways so as to take hold of a large part of the sole to which they are bolted.

Many ingenious designs of axle-boxes have been made to guard against endways play and the consequent oscillation of the body as the brasses become worn at their ends, but it is impossible to refer to these in detail. The general result of experience is, however, in favour of great simplicity in the axle-box, and it is better to replace brasses when they become even slightly worn in preference to adopting plans for allowing the axle-box to run with worn brasses.

The question of lubricant is of great importance, and care is required in the selection of the oil or grease to be used. The grease generally used is composed of something like the following ingredients:—

Proportions for making carriage and waggon grease.

	For Winter	For Summer	For very hot weather
	lbs.	lbs.	lbs.
Russian tallow . . .	214	342	426
Palm oil	240	210	210
Soda	20	18	18
	gallons	gallons	gallons
Water	64	48	48

The quality of oil employed differs greatly on different lines, some carriage superintendents employing crude oil and others a high class oil. It is probably wise to spare no expense in getting a good lubricating oil, as, apart from its value in lessening the tractive force required and diminishing the chances of hot axles, it saves the labour of continually oiling the axles, which is necessary with inferior oil. An axle-box oiled with $1\frac{1}{2}$ pints best oil, costing perhaps 5 shillings per gallon, has been known to run on a busy railway for twelve months without the oil being replenished, while

with inferior oil the axles-boxes require much more frequent attention. The ordinary custom is to fill up the axle-boxes from time to time, so as to keep the space intended for the oil always nearly full, and it is found that with the best oil the boxes need not be supplied more than once a month, whereas with inferior oil they must be filled up much more frequently.

The tractive force required to drag a train on a level line has to overcome the resistances due to the axle friction, the friction of the wheel against the rail, and the resistance of the air. These elements of resistance must be always present, but their amounts are susceptible of much modification.

The consideration however of the amounts of these several elements of resistance is generally regarded as belonging more particularly to the subject of the locomotive engine, and to the determination of the total resistances which it has to overcome. The experiments which have been made, and the methods which have been adopted for calculating the amount of these several resistances, will not, therefore, be dealt with here, except in général terms; but the subject is one which calls for more exact attention, and for more careful experimental treatment than it has received.

The resistance of the air even in calm weather is a large element in the total resistance to trains at high speed. In this case the air offers resistance first by increased pressure on the head end of the train accompanied by decreased pressure on the tail-end of the train; secondly, by similar resistance against all the projecting parts of the carriages; and lastly, by the friction of the air against the sides of the carriages. With a wind right ahead or right astern these elements of resistance are simply modified in amount.

With an adverse wind blowing partly on the end and partly on the side of a train, the resistance on the ends of the train is supplemented by similar resistance in a greater or less degree at the ends of each carriage. A train carries along with it a considerable body of air, so that the air

between the carriages is practically going along with the same speed as the train, and if there is a side wind this air, accompanying the train, is continually being displaced and replaced by fresh air, to which in turn new velocity forward has to be communicated by the opposing surfaces of the ends of the carriages.

A further cause of resistance, due to a side wind, is that it tends to force all the carriages of a train against the leeward rail. This fact, owing to the conical shape of the wheels, brings a larger diameter of the leeward wheels upon the rails, and a smaller diameter of the windward wheels, tending to cause each carriage to run in a curved path, and the leading end of the carriage to turn towards the wind. Each carriage in that case will pursue a serpentine course, or if the force of the wind is sufficient to keep the whole length of each carriage against the leeward rail, the difference in the acting diameters of the wheels has to be accommodated by circumferential slipping of the wheels on the rails. It is manifest that either of these effects adds considerably to the tractive force required. In any case also a sideways wind causes pressure of the flanges of the leeward wheels against the rails, and consequent friction between the flanges and the rails, and also occasions friction between the bearings and the ends of the journals.

A great deal of attention has been given to determining the amount of the resistance of air to trains, but with no very trustworthy results, and but little or no pains have been taken to diminishing it. It seems, however, reasonable to suppose that the resistance due to the air might be much reduced, if a form suitable for the purpose could be adopted for the 'bow' and 'stern' of a train, if the outside of the train were made smooth and without projections, and if the spaces between the carriages were filled in so that air could not pass through. Further, the ill effects of a side wind might be reduced by adopting cylindrical instead of conical wheels, and by diminishing, as far

as possible, the friction due to endways pressure on the journals.

The axle friction is largely dependent on the quality of workmanship in the journals and bearings, and on the lubricant adopted. No very exact information is accessible as to the amount of force required to start a train of modern waggons or carriages, or as to the smaller force necessary to keep it in motion. Speaking broadly, the force required to start a vehicle with grease axle-boxes of good construction on a level and unyielding line, seems to be between 11 and 18 lbs. per ton of load, and to keep such a vehicle in slow motion requires a strain of from 8 to 12 lbs. per ton of load. In the case of a vehicle with good oil axle-boxes, the power required to start it will be more than that for a vehicle with grease axle-boxes, and will vary from 12 to 22 lbs. per ton of load, and to keep such a vehicle in slow motion will require a force of from 2 to 5 lbs. per ton. The great difference between the friction of rest and the friction of motion in each of the above cases is very striking.

The superiority of grease over oil in reducing the friction of rest is accounted for by the fact that a film of grease of sensible thickness remains at all times between the bearings and the journals, but the oil being fluid is to a much greater exfent squeezed out, and has to be replaced after motion has commenced.

It must not be supposed that the figures above mentioned as approximately representing the forces necessary for maintaining a vehicle in motion at slow speeds by any means represent the forces (irrespective of the friction of the machinery of the locomotive, and of the resistance of the wind) required to maintain a train in rapid motion. In that case the friction of the ends of the bearings against the journals, and of the flanges against the rails, the retardation caused by more or less violent blows due to oscillation, the *skewing* of the vehicles on the rails, and the consequent re*sistances* due to sideways sliding and circumferential slip-

ping of the wheels on the rails have to be added. The total amount of resistances will thus be found to largely exceed the amounts above alluded to, and has been estimated at from 14 to 20 lbs. per ton when the train is in motion at from 40 to 60 miles an hour.

The amount of friction of the wheels against the rails varies greatly with the amount of perfection of the road, and whether it be straight or curved. It is also modified by the amount of clearance and the amount of coning given to the treads of the wheels. Though there can be no doubt that coned wheels even on a straight line, swerve sideways on the rails, and on that account, cause considerable friction, and that cylindrical wheels are more fit for a straight line, yet the amount of the friction on a straight line between the rail and the wheel is not a very serious matter. On curves, however, this friction becomes of serious consequence, and it is, as has been explained, in a great measure caused by the wheels being fixed to parallel axles. Experiments on the traction of trains are generally made on straight lines, and therefore the wheel and rail friction seems to be of small importance compared with the axle friction; but there can be no doubt that if this element of wheel and rail friction were obliterated, especially in the case of the more modern lines, where sharp curves are adopted, a considerable saving of tractive force would be effected. Improvement in these respects must be looked for in the construction of carriages in which the axles may be made to run radially to the curves of the line, and in the adoption of wheels running loose on the axles.

It is much to be wished that some of the great companies would set on foot careful experiments with a good dynamometer and well devised self-recording apparatus, placed between the engine and the train, to determine these and many other interesting matters connected with the traction of trains. There can be little doubt that the knowledge gained by such an investigation would be of the

highest value, and would amply repay the cost and trouble of the investigation. Such experiments were carefully made by the Great Western Railway Company in 1848, but the results are only partially applicable to narrow gauge trains, or to modern rolling stock; and, moreover, the experiments did not deal with the resistances on curves.

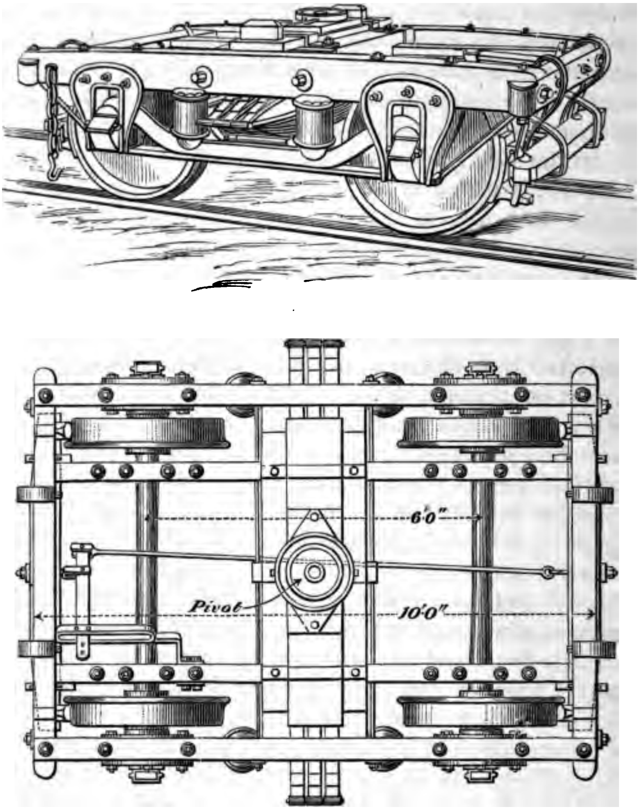
Before concluding the consideration of the under carriage, the bogie mode of construction requires to be alluded to. This is a valuable contrivance for using a small wheel base for a long carriage. It is customary to refer to it as an American invention, from its having been extensively used in the United States. But the fact really is that it was an English invention for dealing with the particular circumstances of the early American railways, on which, from economical considerations, long carriages were desirable, though the railways in question had sharp curves, and were laid with a rough description of permanent way. The first bogie carriages were designed and manufactured at Messrs. Stephenson's works at Newcastle.

The bogie system consists in supporting each end of a carriage on a truck carrying a pivot, and running on two or more pairs of wheels placed close together. The bogie truck, having a very short wheel base, can run round sharp curves without danger, as the positions of the wheels on the railway is dependent on their position relatively to the truck, and not on their position relatively to the entire carriage. A carriage of great length, often as much as 80 ft., can thus be mounted on bogie trucks, with a rigid wheel base of no more than seven or eight feet, and though the axles of each bogie truck are parallel, they are from the shortness of the wheel base always more nearly radial to the curves of the railway than the axles of ordinary carriages. A drawing showing the details of the bogie trucks is given in fig. 197. The American carriages are designed as shown in fig. 198, and examples of this mode of construction have been recently brought into this country in the Pullman cars

which are exceptional carriages made on the American plan, and finished with great elaboration, not to say extravagance, in inlaid woods and gilding, so that one car sometimes costs as much as 5,000*l.* The Pullman cars are fitted with sleeping berths, refreshment accommodation, lavatories, and w.c. arrangements, and are used in some of our fastest express trains chiefly for long journies. The amount of dead weight as compared with paying load is very great in these carriages.

In the best modern ordinary bogie trucks for carriages the pivot is placed on a transverse beam which can swing slightly from side to side, and which is well provided with numerous springs as shown in fig. 197. In the Bissell bogie which is much used for locomotives and for vehicles which have a certain amount of rigid wheel base, independent of the bogie truck, the weight of the end of the vehicle is supported on sliding surfaces on the bogie truck, but the pivot is not placed over the bogie truck but is bracketted out from it and placed between the bogie truck and the rigid wheel base of the central part of the vehicle. This arrangement is for engines and for such vehicles as those above referred to, superior to the ordinary bogie, which however answers well for vehicles which have no rigid wheel base, and which are wholly supported on the bogie trucks. The same principle as that of the Bissell truck is carried out in carriage and waggon stock, by what is called the castor system, in which the wheel frame is pivoted at a short horizontal distance from the axles; by this contrivance the axles can place themselves radially to the curves, and the wheels act like the castors used for furniture. There are other systems by which the axles can be made to run radially on curves, and it is to be hoped that some of them will be brought to a sufficient amount of perfection to enable them to be generally adopted. There can be no doubt that the system of parallel axles is a mechanical mistake, and can only be justified by the difficulty which has been experienced in finding a satisfactory substitute. A most important matter,

and one which must be kept steadily in view, is that any arrangement for making the axles self-adjusting to the radius



PLAN

Fig. 197. Bogie truck.

of curves, should be such as will also ensure that the wheels *shall* run in a true straight line on straight parts of the rail-

way, and shall not have a tendency to diverge sideways in the event of their leaving the rails.

The running of the Pullman car trains is described as being peculiarly free from oscillation, and this can be well understood to be the case on our well-laid English lines. But there are many serious disadvantages in the American carriages for ordinary use both constructionally and in point of comfort. Constructionally they are certainly weaker to resist the effects of collision than English carriages with their numerous cross partitions, and if one of the ordinarily used bogies is thrown off the line there is a greater chance of a disaster from the slewing of the bogie than if the same accident happens to the wheels of an ordinary carriage. Many instances are well-known of ordinary carriages which have accidentally left the rails, being dragged for a long distance, and eventually regaining the rails without serious injury to the passengers, and this is less likely to happen in the case of existing bogie trucks, as they tend to assume a more or less oblique position when off the line.

The internal arrangements of the ordinary American carriages do not in point of comfort compare with our best English carriages, and the grouping of so many passengers in any one carriage, even if it be fitted up like a Pullman day car is often productive of much discomfort. In a long carriage carried on bogie frames the sides of the carriage

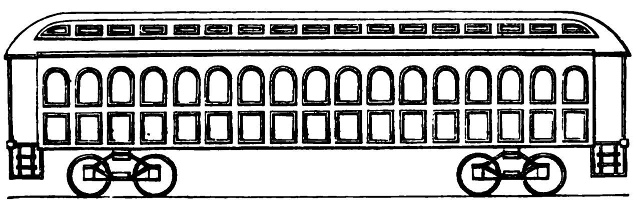


Fig. 198. American carriage.

are constructed in the form of trusses at least as high as the windows, and the trussing often extends to the full height of the carriage. There are consequently seldom or never

any doors at the sides, as they would interfere with the framework of the trussing. Thus all the passengers have to enter and leave these long carriages, which often hold seventy or eighty people, by two doors, one at each end of the carriage, and where there is much traffic great crowding, inconvenience, and delay result. In travelling, one passenger often wants a window open while another wants it shut, and one set of passengers want to talk while others want to sleep, and in many cases, such as when invalids travel, the want of privacy is much felt. In an American carriage an open window not only affects the passengers sitting by it, but causes a draught to reach perhaps twenty or thirty people. The constant passing and repassing of passengers in and out of the carriages is disagreeable, and the conversation carried on in a large carriage is often a nuisance to many of the travellers. It is to be hoped that the plan of the American carriages will not be generally adopted in this country, though for special purposes, such as sleeping cars, these long vehicles may no doubt be usefully employed.

It is a question whether all that is done by the bogie form of construction cannot be carried out on all our main English lines, which have easy curves and good permanent way, by the articulated and rigidly coupled train, in which intercommunication by passages between the carriages could easily be arranged when it is desired. But there can be no doubt that where the curves are sharp, and there is a necessity for long carriages and for a high rate of speed, the bogie may be advantageously adopted.

In the case of waggon stock the bogie frame would be useful if very large trucks were an advantage, but this is not found to be the fact. The convenient way of working goods traffic is to load trucks completely for particular stations, and for the goods train to drop the loaded trucks at their stations, to be unloaded after the train has gone. It is also of much importance that goods trucks should be easily

manœuvred by a few men or by a single horse. Thus moderate-sized trucks, which will carry from seven to ten tons, are found the most convenient size, and such trucks can be well constructed without a bogie frame.

Carriage Bodies.

The bodies of the carriages and waggons in use in this country, which rest on the underframes described above, cannot be treated with any minute examination within the limits of this chapter. The mode of fitting-up the carriages of the different classes should aim at giving the most comfortable seat possible with the expenditure permitted for the description of carriage. Probably no armchair in any library is more comfortable, apart from the oscillation, than a seat in a new first-class carriage on our leading railways, and there appears to be little room for improvement in the size and in the arrangement of the cushions of those carriages which carry three passengers on each side with an arm between each seat. One important thing to be kept in view is, to so arrange the padding of seat, elbows, back and head rests, that it can be easily taken out and cleaned. The amount of dirt collected in first-class carriages, especially in the corners formed by the back and head rests, is very great, and it is advisable not to carry the padding quite home into the angles. Cloth or morocco leather is the best material for cushions, and nearly the worst is velvet, which is unfortunately used on many foreign lines for first-class carriages, and has been mistakenly chosen for those Pullman cars which are called by the high-sounding name of Palace Cars.

The second-class carriages have been vastly improved in comfort of late years, but it is to be lamented that imitation leather, or, as it is sometimes called, American cloth, has been largely introduced for the seats and back cushions. This material is hard and nearly unabsorbant, and forms a hot and uncomfortable seat if it be occupied

for any length of time. The stout woollen material or rep adopted on some lines for second-class carriages is much superior in comfort to American cloth, and it is to be hoped will altogether replace it. Second-class carriages would be further improved if the seat cushion were placed over sacking or netting instead of over a flat board.

A well-known example of a comfortable wooden seat is that of the seat of the well-known Windsor chair, and the seat of a modern third-class carriage which is usually cushionless may be made equally comfortable if it be carefully shaped in the same manner to accommodate the curves of the body. A flat wooden seat which was the form originally used for third-class carriages is unnecessarily uncomfortable. On some lines the seats of third-class carriages are nowadays stuffed with horsehair and covered with a woollen material.

The partitions of some carriages, particularly those of second and third-class on short traffic lines, are often not carried up to the ceiling. Where this is the case the partitions should be carried up beyond the level of the head of a man when sitting down, so as to avoid draughts from open windows in adjoining compartments.

The lighting of carriages in this country at night is by no means satisfactory, except where gas is used, but there can be no good reason why with a little care to the subject a light good enough to read by with comfort should not be given in all carriages. The arrangements with regard to foot-warmers, except on some of the lines from London to the North, are not worthy of the companies. Probably, if the number of portable hot water-tins required is a serious difficulty, the carriages could be warmed from the engine without much trouble. In respect of lighting and warming the carriages English railways contrast unfavourably with those of other countries.

Some improvement may well be attempted in smoking carriages, which require additional ventilation, and this

might easily be given by well-arranged cowls on the roof. On the whole, however, the best modern carriages leave but little to be desired, and the advantages of competition between railway companies have nowhere been more conspicuous than in the improvements which have been voluntarily made in the carriage stock.

The sizes of some of the compartments of carriages now used in this country are given below, and in a second column are given the sizes of similar compartments thirty years ago, by which an idea will be given of how much our rolling stock has improved in size and comfort.

Comparison of length, width, height, &c., of compartment of passenger stock in 1875 *and* 1845.

		Length of compartment between partitions.		Width of compartment.		Height of compartment at centre.		Depth of seat from front to back.		Width of seat for each person.		Height of doorway.		Width of doorway.	
		ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.
First Class	1875	6	3½	6	9	7	0	1	7	2	2	6	0	2	1
	1845	*5*	*5*	*6*	*6*	*5*	*6*	*1*	*5½*	*2*	*1*	*4*	*10¾*	*1*	*10*
Second Class	1875	5	10	7	9	7	0	1	5	1	6½	6	0	2	1
	1845	*4*	*7*	*6*	*0*	*5*	*6*	*1*	*2½*	*1*	*6*	*4*	*10*	*1*	*7*
Third Class	1875	5	3½	7	9	7	0	1	4	1	6½	6	0	2	1
	1845	*4*	*2*	*6*	*10*	*5*	*9*	*1*	*3½*	*1*	*4½*	*5*	*2½*	*1*	*7*

The woods used for the bodies of carriages are usually mahogany, oak, and teak, for external work, and deal for the internal partitions. The roofs are generally covered with boarding, over which painted canvas is laid. It is of the greatest importance, in order to prevent the bodies from being affected by the weather, that all external parts should be protected by paint or varnish. Many people prefer the

appearance of the wood simply varnished, but there is little doubt that painted carriages can resist the weather better than varnished carriages, and that they are in the long run the more economical. A great deal of confusion would be avoided if standard colours were adopted for the different classes of carriage. Much time is uselessly wasted in passengers searching for their class of carriage, and this is particularly the case in suburban and metropolitan lines. Another great improvement would be in paying more attention to distinguishing the trains or, where necessary separate carriages, by boards on which their destination should be legibly painted, placed in positions on the carriage where the boards would be visible when the train is standing at the platform. This is particularly necessary on the metropolitan and suburban lines, but the notice boards on the carriages are usually very indistinct, as if railway managers were ashamed of them, and they are often so placed that they cannot be seen well at any time and scarcely at all at night.

It is impossible to enter minutely into the several details of the fittings of the different classes of carriages, such as the kinds of windows, doors, handles, steps, lamps, and other fittings, as any attempt to deal with such matters would require a space far beyond that now available.

The same remark applies to the mode of constructing the upper parts of waggon stock. The great point aimed at is that the waggons should be suitable to the nature of the traffic for which they are destined, and to the places to which they have to go. Thus there are low-sided, high-sided, covered, and uncovered trucks ; some, such as coal or ironstone waggons, have trap-doors in their bottoms by which their load is discharged downwards ; all trucks as a rule, discharge at their sides if required, and some at their ends as well. The wood generally employed for the upper work of trucks is oak and deal, and in the best waggons all edges and angles are protected and strengthened by wrought

iron. The wear and tear of waggon stock is very great, and it is wise to avoid spending too much on the upper work of the waggons, but to make the underframes very strong, so that they may receive new bodies when required.

Breaks.

This very important subject has recently been investigated by the Royal Commissioners on railway accidents, who have examined and experimented with most of the breaks invented up to the present time, and the results of their labours will soon be in the hands of the public. It will therefore be only necessary to refer to this question in general terms, and not to enter into the details of the several new breaks, which will be found completely described, both as to their construction and performances, in the Report of the Royal Commission.

There are two modes of arresting the speed of a train,

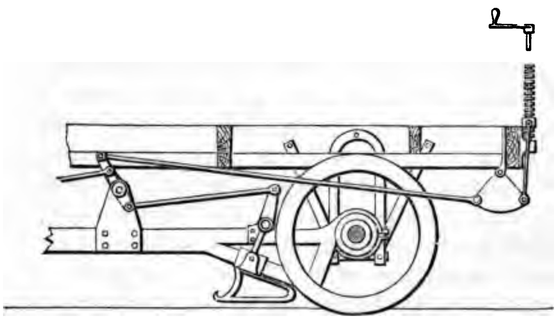


Fig. 199. Slipper break.

viz. exerting pressure on the periphery of the wheels and so arresting, or partly arresting, their rotation; or by what is called the slipper break or by the clip break, by which pressure is exerted directly on the rails.

The slipper break (shown in fig. 199) consists of an arrangement of levers and screws by which some of the weight of the break van is taken from the wheels and

transferred to iron blocks which are pressed downwards so that they slide like sledges on the rails. The arresting power of the slipper break is due to the coefficient of friction of iron against iron multiplied by the weight which can be made to bear on the slippers. The clip break is an apparatus by which the rail is gripped by the two sides of an iron clip which through the agency of screws or levers are caused to clasp the rail tightly between them. Its power of arresting the train is independent of the weight of the train, and is due to the power of the screws or levers which cause the clip to grasp the rail. There can be no doubt that the clip break can be made to act with great efficiency, and is in some respects better than the break which tends to arrest the rotation of the wheels. The disadvantage of the clip break is that it can only be satisfactorily used on a line free from junctions or points and crossings.

The break, applied to the wheels possesses for the traffic of this country the greatest practical advantages, and all or almost all the modern breaks are based on the principle of applying the break to the wheels. One disadvantage of so applying the break is. that it throws a severe strain on the wheels and journals, and that it often stops the rotation of the wheels altogether, causing the wheels to be unequally worn, and to become flat where they have acted as sledges on the rails. This objection may to a great extent be obviated by applying the break to a large number of wheels, and by graduating the pressure on the break blocks so that there may be no necessity for completely stopping or skidding any of the wheels. The power applied to the ordinary break is generally derived from the guard's manual strength acting through the agency of levers, screws, or other mechanism on the wooden or iron blocks which are pressed by these means against the treads of the wheels. The breaks of goods and mineral waggons are usually applied by means of a long lever, as is shown in fig. 200. Those of carriages or break

vans are generally worked by a screw (fig. 201) with a handle or wheel in the van, by which the rod attached to the

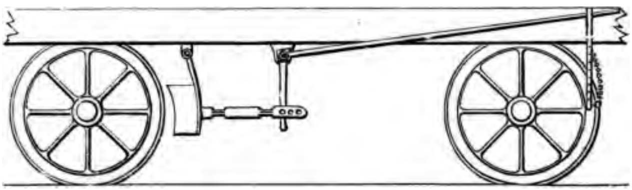


Fig. 200. Waggon break.

break is pulled or pushed in order to bring the blocks in contact with the wheels.

Where breaks are applied to more than one wheel by the movement of any one lever or screw, care should be taken that the pressure is equally distributed among the several wheels or surfaces of the break blocks. This point

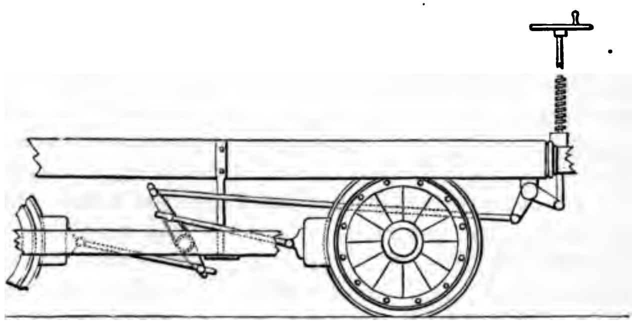


Fig. 201. Carriage break.

is too often neglected, and it is no uncommon thing to see one wheel of a guard's break van skidding and the other wheels revolving freely. The pressure on one wheel ought to be the fulcrum by which pressure is brought on to the other wheels, and this can very easily be carried into effect. The size of the blocks must be proportioned to the power of the lever or screw, and to the desirability or the reverse of giving

the breaksman power enough to skid the wheels. When the blocks of wood are worn away they are easily replaced by new blocks, and the machinery which works the break must be so arranged that it will be operative with either new or worn blocks.

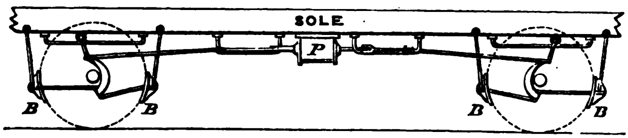
Until lately breaks such as the above were only applied to the wheels of the particular vehicle on which the lever or screw is placed, but continuous breaks are now often used and will no doubt before long be universally adopted. The mode by which continuous breaks are applied varies considerably, but speaking generally these breaks may be divided into those which are worked by weights or springs, those which are actuated by the wheels of the train itself, and those which are worked by pistons actuated by steam, compressed air, or water, or by atmospheric pressure acting on a partial vacuum created on the opposite side of a piston.

One of the most important points to be aimed at is that the break shall be capable of being applied with rapidity and certainty when cases of necessity arise, so that no appreciable time shall be occupied in acquiring the power necessary to apply the break with its full intensity, but that the full power of the break shall be at once available. A further necessity of a really satisfactory break is that it shall be such as can be used in the ordinary working of a train, and not as a special apparatus to be used only in case of a threatened accident. It is not desirable, on account of the unavoidable strains and shocks which the process occasions, that as a rule the full power of the break should be applied suddenly to a train at full speed, and it is much more advisable that the break should be applied gradually. Thus a satisfactory break is one that can be put on gradually in the every-day working of the traffic; but should also be capable of being used at its highest power instantaneously when necessity arises. Breaks that are put on by *releasing* a spring or a weight which has previously been *wound up* or has been previously raised, fulfil the necessity

of the break being available at its full power instantaneously; but they do not well carry out the other necessity in being convenient for ordinary working, as it is difficult to apply such breaks gradually or to take them off promptly.

A description of break has been much used, which is actuated by the wheels of the train and is worked through the wheels of the guard's van being made to act on a friction wheel which winds up a chain and tightens up the break blocks of any number of carriages. This is the principle of Clark's well-known break, which is in many respects a very satisfactory apparatus. The breaks are taken off, and when not in use are kept from touching the wheels by a weight or a spring under each carriage, and thus when the breaks are required to be applied suddenly, a considerable amount of work has to be done in raising the weights or compressing the springs in addition to that required to apply the requisite pressure; nevertheless, these breaks can be applied with considerable rapidity and certainty, and they have stood the test of long experience on many English railways.

The remaining breaks are those which are worked by means of a piston (fig. 202), which by its backward or for-



B. Break Blocks
P. Piston

Fig. 202. Piston break.

ward movement applies or releases the break blocks. This description of break includes the systems of Westinghouse, Smith, and others.

The chief difference between these piston systems consists in the mode by which the pistons are actuated. Thus in the steam break which is an extremely valuable break for engines and tenders, but which cannot well be applied to

the other wheels of a train on account of the condensation of the steam, the pistons are worked by steam pressure from the boiler of the locomotive ; in the Westinghouse air break a pumping engine on the locomotive compresses air which is conveyed by pipes to every piston ; in the vacuum break the pistons are worked by atmospheric pressure against a partial vacuum produced by means either of a steam jet or an air pump, on the locomotive. In the hydraulic break the pressure on the pistons is derived from the pressure of a small hydraulic accumulator, which is raised in the well-known way by a small pump worked by a friction wheel driven off the wheel of the break van.

Much ingenuity is shown in all the systems in the arrangements for making and unmaking the joints between the carriages which have of course to be capable of being easily and at any time un-coupled. There are also special contrivances by which, if any portion of the train breaks away from the rest of the train, the breaks are immediately applied, and the pipes are so closed by self-acting valves that the pressure in the pipes is not allowed to escape. It is not possible here, to enter minutely into the construction and working of the several breaks; but, in conclusion, some figures will be given derived from the careful report of the 'Engineering' newspaper on experiments conducted by the committee appointed by the Royal Commissioners on railway accidents, which will show the power of the several breaks in arresting trains of known weight at known speeds and on the same railway. The varying circumstances in these experiments were thus confined to the state of the rails and the pressure of the wind. These elements of disturbance were as far as possible eliminated, and the comparative statement of the work so performed by the different breaks is the most valuable record that exists on this very important subject.

The subjoined tables give a few of the results arrived at in the above mentioned investigation. The experiments given in the following tables are those in which the engine was

not reversed. These have been chosen in preference to those in which the engine was reversed, in order to avoid confusion in comparing the effects of the different breaks. Thus the following tables do not give quite (though they do nearly) the most favourable examples of rapidity in stopping. The trains in all cases consisted of an engine, tender, two break vans, and thirteen carriages, and the total weight of each train is given in Column 1. Column 2 shows the description of breaks used. Column 3 the speed of the train when the breaks were applied. Column 4 shows the distance run after the breaks were applied until the train was stopped. Column 5 gives the time occupied in making the stop. Column 6 shows the state of the rails, and Column 7 the distance which in each case such a train would run after the breaks were applied corrected for a speed of 50 miles an hour. The first table shows the results attained by ordinary breaks. Under favourable conditions the shortest distance in which a train with these ordinary breaks was pulled up was 2,437 ft.

TABLE I.—ORDINARY BREAKS.

Shows the effect produced by the ordinary breaks on the tender and break vans applied by hand on a signal being given, and without reversing the engine.

1 Total weight of train and engine.	2 Description of break used.	3 Speed of train when breaks were applied.	4 Distance run after application of breaks.	5 Time occupied in making the stop.	6 State of the rails.	7 Equivalent distance which would have been run by the trains if the speed when the breaks were applied had been fifty miles per hour.
tons cwt.		miles per hour.	feet.	secs.		feet.
241 10	Ordinary breaks on tender and break vans.	$49\frac{1}{2}$	2389	63	dry	2437
197 8		$49\frac{1}{2}$	3205	86	dry	3270
198 4		$49\frac{1}{2}$	3265	$83\frac{1}{2}$	wet	3331
257 13		$49\frac{1}{2}$	3591	87	wet	3664
204 3		$49\frac{1}{2}$	3705	96	wet	3780

TABLE II.—CONTINUOUS BREAKS.

Shows the effect produced by engine and tender breaks, and the different descriptions of continuous breaks applied simultaneously on a signal being given, and without reversing the engine.

1 Total weight of train including weight of engine.	2 Description of break used.	3 Speed of train when breaks were applied.	4 Distance run after application of breaks.	5 Time occupied in making the stop.	6 State of the rails.	7 Equivalent distance which would have been run by the train if the speed when the breaks were applied had been 50 miles per hour.
tons cwt.		miles per hour.	feet.	secs.		feet.
203 4	Westinghouse Automatic	52	913	19	dry	844
198 4	Clark's Hydraulic . .	52	1212	22¾	dry	1121
186 13	Fay's	44⅓	1165	27½	wet	1471
262 7	Smith's Vacuum . .	49⅓	1448	29	dry	1477
241 10	Clark and Webb's . .	47¼	1337	29	dry	1481
210 2	Barker's Hydraulic .	50¾	1549	32	dry	1503
204 3	Westinghouse Vacuum .	52	1728	34½	wet	1598
197 7	Steel and M'Innes' .	49½	1603	34¼	wet	1636

The best results obtained showed that with the Westinghouse automatic continuous breaks, and under favourable circumstances, a train of thirteen carriages travelling at the rate of 52 miles per hour, could be brought to rest on a level line with the rails dry in a distance of 913 feet, and in 19 seconds of time. This is equivalent to saying that the same train might have entered beneath the roof of Paddington Terminus at a speed of 50 miles an hour, and have been pulled up safely before it reached the buffers at the hotel end of the station.

The state of the rails is a most important factor in the *arresting* power of breaks. It was shown in these experiments that the same break applied to the same train requires

from 30 to 40 per cent. more space to pull up in when the rails are wet than when they are dry. The ill effect, however, of wet rails may be to some extent reduced by sanding the rails from well-contrived sand boxes, which should be so arranged as to be self-acting in cases of emergency.

Probably none of the breaks have yet reached the limit of rate of retardation possible or practicable. The practicable rate of retardation depends on the amount of force which may be safely administered to a train without injury to the passengers. Up to this time the power available to arrest a train has been altogether disproportioned to the necessities of railway travelling and to the forces at work in a train at full speed. The amount of retarding force which may be applied to a train without injury to its inmates has up to this time been much under-estimated, and it may be with confidence predicted that in future the breaks will exceed in power any of those yet introduced.

Intercommunication in trains.

A subject which requires attention is that of the means of communication between the guards and the engine-drivers of trains and between passengers and the guards or drivers. By an Act of Parliament passed in 1868, railway companies are bound to afford means for passengers communicating with the guard and for the guard communicating with the driver in all trains which run 20 miles without stopping. This Act of Parliament was no doubt tentative, and much doubt was expressed at the time of its passing as to the possibility of giving the desired means of communication. This possibility has since been proved to exist, and there seems to be now no valid reason for distinguishing between trains which run 20 miles without stopping and those which stop at every station. Experience has shown that intercommunication is most desirable in the case of all trains, even if they stop frequently, and one of the most fatal accidents of modern times in this country in

which proper means of intercommunication would have been of the highest use, happened to a train which had only left an important station 7 miles off a few minutes previously.

There are two systems of intercommunication in use, viz., a rope attached to bells on the engine and in the guard's van, and electrical apparatus. The rope apparatus has been that most generally adopted; but so far as it has at present been carried out, it cannot be said to be a success. There are formidable difficulties in perfecting any system of rope communication in the alteration in length of a train during its journey. When a train is ascending an incline, all the draw-bars and buffer-springs are extended; but when the train is descending an incline, or entering a station, and when the engine breaks are on, the reverse takes place, and thus the same train will be at one time considerably longer than at another. The rope is therefore apt to hang in loops, and to get foul of parts of the carriages. One arrangement is to put the rope on the off side of the carriages above the doorways. Another arrangement is to pass it through the handles by the sides of the doors. In the former case the rope is liable to get shut into the door if the door is opened; the latter arrangement is liable to the same objection, and is more inconvenient, as trains often have to discharge passengers on platforms on either side of the train. Another plan of rope communication is to pass the rope through the centre of the carriage immediately above the floor. In all these cases when the rope has to be used it is more than likely that a great deal of slack has to be taken up before the bells can be rung, and there must be great uncertainty whether they have been rung or not. Intercommunication is only designed for and allowed to be used by passengers in cases of emergency, and any system which may involve pulling in 10 or 20 feet of slack cord before a signal can be given is very unsatisfactory. Possibly by the use of counterweights some of the difficulties of the slack might be got over; but the other objections

to the rope communication will still remain, and probably will prevent its being retained in the future. The Board of Trade inspectors have reported that at present the rope communication is unsatisfactory, and it is to be hoped that it will be either improved very much or discarded altogether, for at present it is, in many instances, no better than a sham.

The electric system of communication promises better, and has been carried out with success, at least on one line, viz., the South-Eastern Railway. In this case a wire is laid along the top of every carriage (fig. 203) and brought down at each end of the carriage, terminating with a hook at a convenient distance from the ground, so as to be within reach of a man on the platforms of stations or standing on the buffers. There are electric couplings (fig. 204)

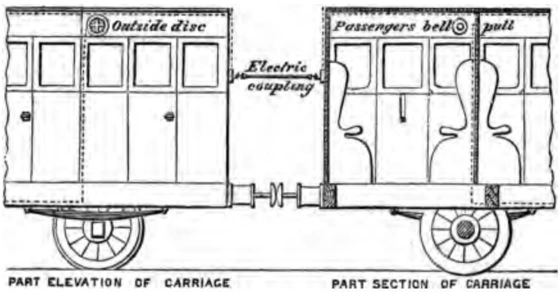


Fig. 203. Electric intercommunication in trains.

provided with loops at each end which fit on to the hooks above mentioned, and as a wire is also placed on the engine, it follows that when all the electric couplings are on their hooks, the whole train is connected together electrically and electric signals can be passed from one carriage to any other carriage or to the engine. The signal is given from the passenger to the guard by pulling out a handle (fig. 205) like a bell-pull from the side of the carriage. The withdrawal of the handle causes a bell to ring in the guard's van and a *small hinged* disc to fly out on the outside of the carriage

in question, to indicate from whence the signal comes. Neither the handle nor the disc can be replaced by the

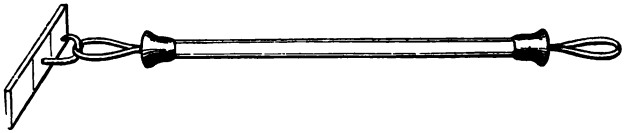


Fig. 204. Electric coupling and hook.

passenger, and any passsenger is liable to a fine of 5*l.* for using the apparatus without good reason. In each guard's van is placed what is called the 'Guard's set' (fig. 206), which has a bell and a key, similar to those described in the block signalling chapter, p. 144. A miniature semaphore signal and a bell (fig. 207), called the 'Engine-driver's set,' is fixed on the engine in front of the driver's face. Each guard

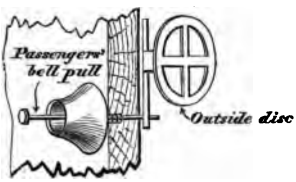


Fig. 205. Bell pull and disc.

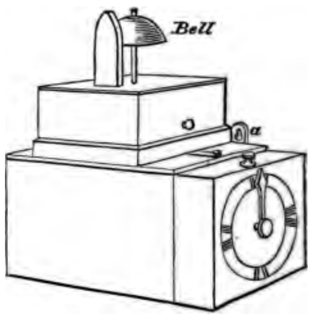


Fig. 206. Guard's set.

can, by either turning the arrow-headed hand round on the dial to particular marks on the dial, telegraph by bell signals to either of the other guards of the train, or by the bell and the miniature semaphore signal on the engine to the driver.

The South-Eastern arrangement works well, and is capable of doing all that is required in the way of intercommunication. It appears, however, to be a mistake in this and almost all other similar systems to make the passenger

telegraph to the guard, and the guard to the engine-driver, instead of the passenger telegraphing to both guard and driver at once. In many cases, in which it is necessary to use the signalling apparatus, it is of the utmost consequence that the train should be stopped quickly. Telegraphing to the guard, and depending on him to forward the message to the driver, may cause the waste of priceless moments, for the guard may be engaged in sorting luggage, or may be in other ways unprepared to forward the signal at once to the driver. It is of course necessary that the guard should also be communicated with, so that he may put on the breaks and take steps to protect the rear of his train immediately it is stopped ; but the more really important thing, particularly now that the block system is so generally adopted, which in itself goes far to protect the train when stopped at unexpected places, is that not a moment be lost in arresting the attention of the engine-driver. The responsibility of stopping a train in all other emergencies is given without question to the engine-driver, who is much better placed than the guards for judging of how to act at critical times, and there can be no good reason why he should not on the occasion of an alarm by the train telegraph be as well qualified as one of the guards to use his discretion as to stopping at once or going on to the first station.

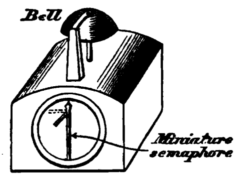


Fig. 207. Engine driver's set.

One very important point to be observed in this and in all other apparatus, which is only called upon in emergencies, is that it should be used in the regular working of the train, so that it may be tested and seen to be in working order. Test signals are often given between the guard and the driver before the train is started, and it is desirable that, if possible, at least once in every journey the apparatus should be used by the guard for starting from or stopping at a station, and the fact of its having been so worked, and

a report on its efficiency, should be entered on the way bill.

With the subject of intercommunication this examination of 'Railway Appliances' is concluded. The title covers so wide a field, and embraces so many matters of importance, that only a passing examination of each in turn has been found possible. The object of this work has been to endeavour to direct attention to the leading characteristics of each of the subjects treated of, so that the younger members of the engineering profession, and any of the public at large who may desire to follow up the study, may be able to examine the well-known works which treat exhaustively of each detail of railway construction, with the advantage of a preliminary knowledge of the general form and use of the appliances in question, and of the aims which should be kept in view in perfecting their design.

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